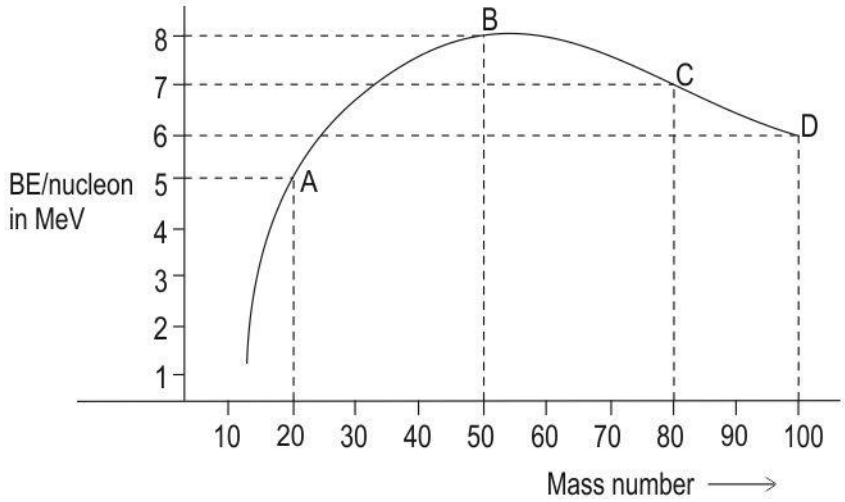
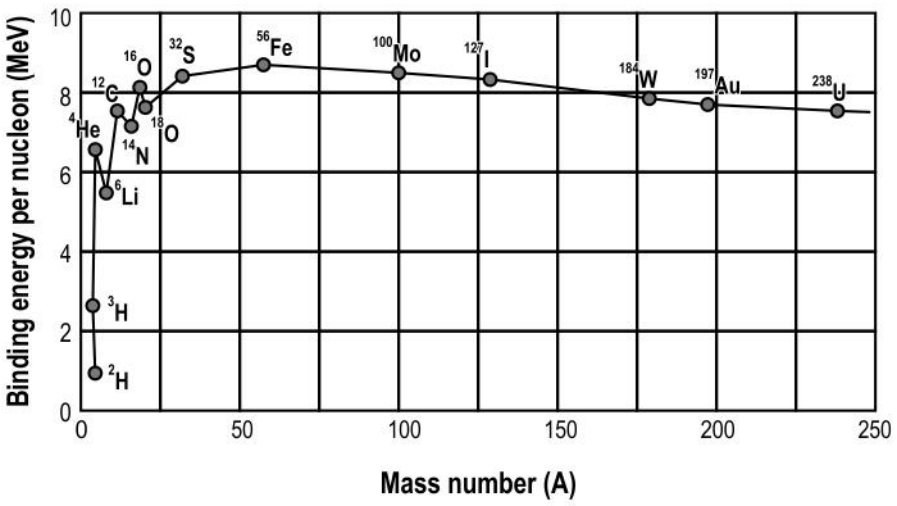
Nuclei

Q.No	Question	Marks
	Multiple Choice Question	
Q.174	A, B, C and D are four different nuclei with different binding energies and mass numbers.  Considering that the below equations (I-IV) are possible, identify the equation/s that would be exothermic. I. D -> B +C II. C -> B + A III. D -> 2B IV. B -> 2A A. only I B. only IV C. only I and III D. only II and III	1
Q.175	A certain nucleus M decays into N which further decays to R by undergoing the reactions shown below. $M \rightarrow N + \beta^-$ $N \rightarrow R + \alpha$	1

	Which of the following options is correct about the above reactions? A. M and R are isotopes. B. N has less number of protons than M. C. The mass number of N is more than that of M. D. Atomic number of R is one less than that of M.	
Q.176	Two alpha particles P and Q deflect by 10° and 120° angles in Rutherford's gold foil experiment. Which of the following is DEFINITELY true about the two particles? A. Impact parameter of P > Impact parameter of Q B. Impact parameter of P < Impact parameter of Q C. Kinetic Energy of P > Kinetic Energy of Q D. Kinetic Energy of P < Kinetic Energy of Q	1
Q.177	Consider the following reaction $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$ Which of the given options is correct for the above reaction if U was initially at rest? A. Momentum of Th will be less than that of He B. Kinetic energy of Th will be less than that of He C. Momentum of Th will be more than that of He D. Kinetic energy of Th will be more than that of He	1
Q.178	The distance of closest approach of an alpha particle is *d* when it moves with a speed *v* towards a nucleus. Another alpha particle is projected with higher energy such that the new distance of the closest approach is d/2. What is the speed of projection of the alpha particle in this case? A. v/2 B. √2v C. 2v D. 4v	1
Q.179	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.	1

	Assertion(A): If an atom has a filled valence shell, the atomic nucleus is stable. Reason(R): The atom with a filled valence shell does not react with other elements. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but reason is true.	
Q.180	An element with an unstable nucleus decays by emitting an α particle and two β^- particles to become a stable atom. Which of the following is true about the new stable atom? A. It is an isobar of the original element. B. It is an isotone of the original element. C. It is an isotope of the original element. D. It has the same proton and neutron number as the original atom.	1
	Free Response Questions/Subjective Questions	
Q.181	Given here is BE/nucleon vs. Mass number curve.  (a) Arrange the following nuclei in the ascending order of the ease with which a nucleon can be taken out of the atomic nucleus:^{6}Li, ^{16}O, ^{56}Fe, and ^{238}U. State the condition basis on which the arrangement is done. (b) If 8 protons and 8 neutrons are combined into the following nuclei/combination of nuclei, estimate which one of them will release the most energy. Show the working.	4

<table>
<tr><td></td><td>i. One ^{12}C nucleus and one ^{4}He nucleus

ii. Four ^{4}He nuclei

iii. One ^{16}O nuclei

(Use BE/A of ^{12}C = 7.6 MeV; BE/A of ^{4}He = 6.8 MeV; BE/A of ^{16}O = 8.2 MeV)</td><td></td></tr>
<tr><td>Q.182</td><td>A pair of nucleons were attracted to each other when they were separated by a distance d, however, when the distance was increased, after a certain separation they started repelling each other. Identify this pair and explain this behavior.</td><td>2</td></tr>
<tr><td>Q.183</td><td>The table below represents the binding energy per nucleon and mass number of a few elements.

<table><tr><th>Element</th><th>Mass Number</th><th>Binding energy per nucleon (MeV)</th></tr><tr><td>Hydrogen</td><td>1</td><td>0</td></tr><tr><td>Helium`</td><td>2</td><td>7.4</td></tr><tr><td>Lithium</td><td>6</td><td>4.9</td></tr><tr><td>Iron</td><td>56</td><td>8.8</td></tr><tr><td>Gold</td><td>197</td><td>7.7</td></tr><tr><td>Uranium</td><td>238</td><td>7.5</td></tr></table>
Study the table and answer the following questions.
(a) What does the binding energy per nucleon of hydrogen signify?
(b) Which element has the highest mass defect per nucleon among the given elements? Give reason.
(c) Of lithium and gold which element has a more tightly bound nucleus? Give reason.</td><td>3</td></tr>
<tr><td>Q.184</td><td>Given below are two probable nuclear reactions:

$_{Z}^{A}X$ ----------> $_{Z}^{A-1}X + {}_{0}^{1}n$ (1)

$_{Z}^{A}Y$ ----------> $_{Z-1}^{A-1}Z + {}_{1}^{1}p$ (2)

a. State the condition under which nuclear reactions can occur spontaneously without any external energy input.

b. Using the following data of nuclear masses, identify which of the given reactions can occur spontaneously without any external energy input.</td><td>3</td></tr>
</table>

	Mass of ${}_{Z}^{A}X$ = 230.033927 u $Mass_{proton}$ = 1.0078 u $Mass_{neutron}$ = 1.0087 u Mass of ${}_{Z}^{A-1}X$ = 229.033496 u Mass of ${}_{Z}^{A}Y$ = 230.049289 u Mass of ${}_{Z-1}^{A-1}Z$ = 229.032089 u	
Q.185	Removing one proton from ${}_{12}^{23}Mg$ results in the formation of ${}_{11}^{22}Na$. If the binding energy per nucleon for ${}_{12}^{23}Mg$ nucleus is 7.9 MeV/A and that of ${}_{11}^{22}Na$ is 8.11 MeV/A, determine the energy required to remove one proton from ${}_{12}^{23}Mg$.	2
Q.186	The heaviest stable nucleus is ${}_{83}^{209}Bi$ and the lightest stable nucleus is ${}_{1}^{1}H$. Find the ratio of: a. Volume of the two nuclei b. Density of the two nuclei	2
Q.187	The carbon-13 nucleus has one additional neutron as compared to nucleus of carbon-12. The difference in the BE of these two nuclei is approx. 5 MeV. Take mass of neutron = 1.0086 u. Using this information, determine the difference in the atomic masses of these two nuclei.	2

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.174	C. only I and III	1
Q.175	D. Atomic number of R is one less than that of M.	1
Q.176	A. Impact parameter of P > Impact parameter of Q	1
Q.177	B. Kinetic energy of Th will be less than that of He	1
Q.178	B. √2v	1
Q.179	D. Assertion is false but reason is true.	1
Q.180	C. It is an isotope of the original element.	1
Q.181	(a) ^{6}Li , ^{238}U, ^{16}O, ^{56}Fe Lesser is the BE/nucleon, lesser is the energy required, hence it is easier to remove the nucleon from the nucleus. [0.5 mark for the correct arrangement][0.5 mark for the correct condition] (b) i. One ^{12}C nucleus and one ^{4}He nucleus BE/A of ^{12}C = 7.6 MeV BE/A of ^{4}He = 6.8 MeV Total BE = 12 x 7.6 + 4 x 6.8 = 118.4 MeV This is the total energy released in the case of forming One ^{12}C nucleus and one ^{4}He nucleus. [1 mark for the correct calculation of energy released in the reaction] ii. BE/A of ^{4}He = 6.8 MeV Total BE = 4 x 6.8 x 4 = 108.8 MeV [1 mark for the correct calculation of energy released in the reaction] iii. BE/A of ^{16}O = 8.2 MeV Total BE = 16 x 8.2 = 131.2 MeV	4

	Maximum energy is released in case of formation of one ^{16}O nucleus using 8 p and 8 n. [1 mark for the correct calculation of energy released in the reaction]	
Q.182	These particles are likely to be protons. The change in behaviour from attraction to repulsion is due to the nuclear force and the electromagnetic force. Initially, when the protons are close together (at a distance 'd'), the strong nuclear force, which is attractive, overcomes the electromagnetic repulsion between the positively charged protons. However, as the protons move farther apart (beyond a certain distance), the strong nuclear force diminishes because it acts only over short distances and the electromagnetic repulsion dominates as the distance between the protons increases.	2
Q.183	(a) Binding energy per nucleon of hydrogen is 0 MeV which signifies it does not require energy to separate the nucleons in the nucleus of hydrogen as it has only 1 proton and no neutrons. (b) The binding energy per nucleon of iron is the maximum. (0.5 marks) This implies that its mass defect per nucleon is the maximum. (0.5 marks) (c) The higher the binding energy per nucleon, the more tightly bound will be the nucleus. (0.5 marks) Thus gold has a more tightly bound nucleus as it has greater binding energy than lithium. (0.5 marks)	3
Q.184	a. The nuclear reaction that occur spontaneously without any external energy input, are possible, if the Q value of the reaction is positive. Alternatively, sum of the reactant masses exceeds the sum of product masses. [1 mark for the statement of the correct condition] b. Reaction 1: $_Z{}^AX$ ---------> $_Z{}^{A-1}X + {}_0{}^1n$ Mass of the reactant $_Z{}^AX$: 230.033927 u Sum of the masses of the products = 229.033496 u + 1.0087 u = 230.042196 u Since the sum of product masses exceeds the mass of the reactant , reaction 1 is not possible. [1 mark for the correct result] Reaction 2: $_Z{}^AY$ ---------> $_{Z-1}{}^{A-1}Z + {}_1{}^1p$ Sum of the masses of the products = 229.032089 u + 1.0078 u = 230.039889 u	3

	Mass of the reactant ${}_{Z}^{A}Y$: 230.049289 u Since the sum of product masses is less than the mass of the reactant , reaction 2 is possible. [1 mark for the correct result]	
Q.185	Total BE of ${}_{12}^{23}Mg$ = 7.9 x 23 MeV Total BE of ${}_{11}^{23}Na$ = 8.11 x 22 MeV [0.5 mark for each expression for BE] Energy required to remove one proton from ${}_{12}^{23}Mg$ is (7.9 x 23) – (8.11 x 22) = 181.7 – 178.4 = 3.28 MeV [1 mark for correct final result]	2
Q.186	a. Radius of nucleus, $r = r_o A^{1/3}$ where $r_o = 1.2 \times 10^{-15}$ m Volume of the nucleus = $= (4/3)\pi r^3 = (4/3)\pi r_0^3.A$ Ratio, $\frac{volume\ of\ 209Bi}{volume\ of\ 1H} = \frac{209}{1} = 209$ [1 mark for correct formula & final result] b. Density of a nucleus = mass/volume = $m_n A/(4/3)\pi r_0^3.A$ = constant and independent of A. Ratio of densities of Bi and H is 1 [1 mark for correct final result]	2
Q.187	Difference in BE of C12 and C13 is 5 MeV The corresponding Mass defect that resulted in the above difference in BE = 5/931 = 0.0054u [1 mark for the calculation of mass defect] Since C13 nucleus has one extra neutron of mass 1.0086 u as compared to C12 nucleus, the difference in atomic masses between C12 and C13 is given as, 1.0086 u - 0.0054u = 1.0032 u. [1 mark for the correct final result]	2