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Year 12 Physics

Tutorial 9.8.D – Artificial Transmutations

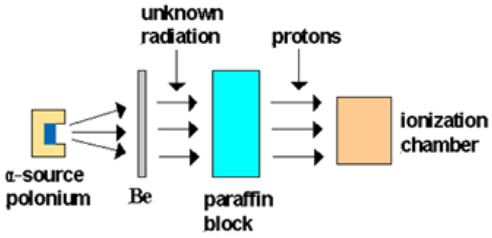
Module	9.8 – From Quanta to Quarks
Topic	9.8.D – Artificial Transmutations
Name	**Date**

Data

Particle	Mass (u)
Electron	0.000549
Proton	1.007277
Neutron	1.008665
Hydrogen-1	1.007825
Alpha particle	4.002603

Particle	Mass (u)
Nitrogen-14	14.00307
Oxygen-17	16.99913
Krypton-36	91.8973
Barium-141	140.9139
Uranium-235	235.0439

1. Explain how Chadwick discovered the neutron using the experiment shown, the laws of conservation of momentum and energy and appropriate nuclear equations.



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2. Explain how neutron scattering experiments have be used to probe the structure of matter.

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3. Compare the concept of mass defect with binding energy.

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4. Using the data provided, calculate the mass defect and binding energy per nucleon for a helium nucleus.

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5. Explain how binding energy per nucleon is related to nuclear stability.

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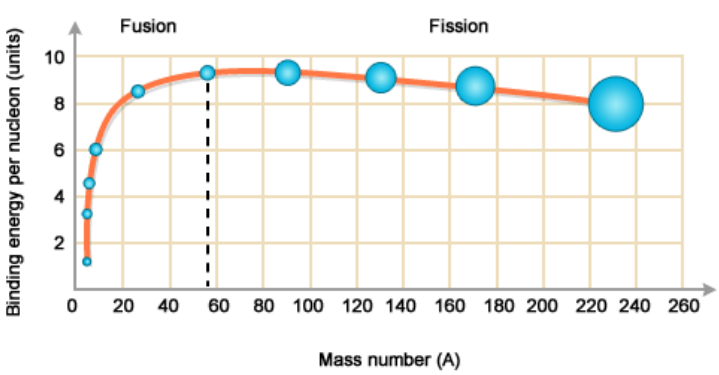
6. The graph shows a binding energy per nucleon curve against nucleon number.



(a) Describe the general features of the binding energy curve for the stable nuclides.

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(b) What does the near constant value of the binding energy per nucleon imply about the strong nuclear force?

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(c) Account for the decrease in binding energy for the nuclides with mass numbers greater than 70.

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7. Explain why Fermi initially thought that bombarding a uranium-235 element with a thermal neutron would create a synthetic (transuranic) element.

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8. In 1986 at Chernobyl in the Ukraine a nuclear accident occurred and where the reactor core exploded and exposed the graphite moderator of the reactor to air, causing it to ignite. The resulting fire sent a plume of highly radioactive smoke fallout into the atmosphere and over an extensive geographical area. Tonnes of lead, sand and boron were dumped on the reactor soon after. What was the purpose of the boron in the mixture?

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9. Account for the use of a moderator in a nuclear reactor and give some examples of the materials used.

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10. Explain how control rods are able to regulate the rate at which fission occurs in a nuclear reactor.

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11. Account for the use of thermal neutrons in a nuclear fission reactor and explain how they are obtained.

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12. Determine the energy released in the following fusion reaction.

$^{4}_{2}He + {}^{14}_{7}N \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$

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13. The following reaction is typical of the fission processes occurring in a nuclear reactor.
$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3{}^{1}_{0}n$

(a) Explain how it is that this reaction sometimes becomes a chain reaction.

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(b) Using the data provided, determine the energy released in each fission.

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(c) Complete the following table to show some of the other possible fission fragments for uranium-235.

$^{236}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow X + Y + x\,{}^{1}_{0}n$

X	*Y*	*x*
$^{140}_{54}Xe$		2
	$^{95}_{39}Y$	2
$^{134}_{52}Te$	$^{100}_{40}Zr$	
$^{147}_{59}Cs$		3
	$^{92}_{36}Kr$	3
	$^{85}_{35}Br$	3
$^{147}_{59}Pr$		3
$^{127}_{50}Sn$		2

14. When uranium-238 decays an alpha particle of 4.195 MeV energy is released. Yet calculations of the mass difference for the decay indicate that 4.267 MeV is released. Where is the missing energy?

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15. The Manhattan Project was a research and development program by the United States with the United Kingdom and Canada, that produced the first atomic bomb during World War II. Identify some positive and negative impacts on society of the Manhattan project.

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