

ملخص وأوراق عمل الدرس الأول Nucleus The من وحدة particle and Nuclear physics انسباير منهج



تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ← المناهج الإماراتية ← الصف الثاني عشر المتقدم ← فيزياء ← الفصل الثالث ← ملفات متنوعة ← الملف

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المزيد من مادة
فيزياء:

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التواصل الاجتماعي بحسب الصف الثاني عشر المتقدم



صفحة المناهج
الإماراتية على
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

المزيد من الملفات بحسب الصف الثاني عشر المتقدم والمادة فيزياء في الفصل الثالث

مذكرة الدرس الثاني Atom the and Theory Quantum من وحدة Atoms in Electrons منهج انسباير

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أوراق عمل الدرس الأول التيار الكهربائي من الوحدة الخامسة التيار والمقاومة متبوعة بالإجابات

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MODULE 24



Einstein_AE

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NUCLEAR AND PARTICLE PHYSICS

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Einsteinabdo



Term 3

اينشتاين العرب

Lesson 1 THE NUCLEUS

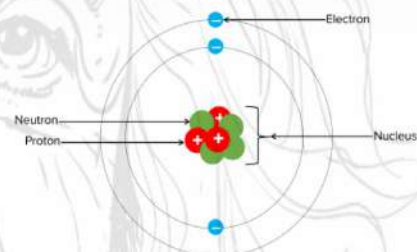
What Is Nuclear Physics?

- Nuclear physics studies the **nucleus of the atom**.
- Chemistry focuses on **electrons**, because electrons determine chemical bonding.
- Nuclear physics **focuses on the nucleus because it**:
 - ✓ Determines the **element**
 - ✓ Controls **nuclear reactions** (radioactivity, fission, fusion)

Nucleons

Nucleons are the particles found inside the nucleus:

1. **Protons**
2. **Neutrons**



1. Protons

- **Symbol:** p^+
- **Charge:** $+e$
- **Mass:**

$$m_p = 1.6726 \times 10^{-27} \text{ kg}$$

- The number of protons is called the **atomic number (Z)**.
- The atomic number **defines the element**.

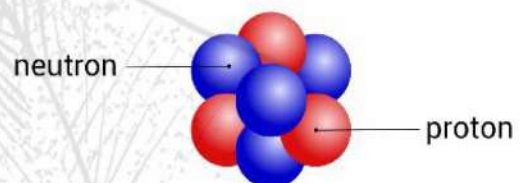
2. Neutrons

- **Symbol:** n^0
- **Charge:** 0
- **Mass:**

$$m_n = 1.6749 \times 10^{-27} \text{ kg}$$

- The number of neutrons is represented by N .
- A neutron is slightly heavier than a proton

nucleus



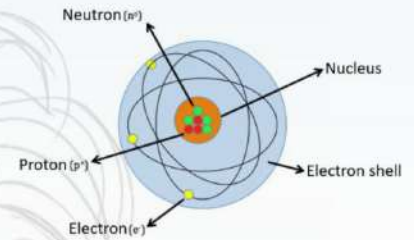
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Atomic Number (Z)

- The **atomic number (Z)** is the **number of protons** in the nucleus.
- It uniquely identifies the element.
- In a **neutral atom**:

Number of protons = Number of electrons



- Electrons are located **outside the nucleus**.

Mass Number (A)

- The **mass number (A)** is the **total number of nucleons** in the nucleus.
- Nucleons include **protons and neutrons**.
- It is given by:

$$A = Z + N$$

Nuclear Symbol Notation

A nucleus is written as:

Mass number
Number of protons
and neutrons in atom



Atomic symbol
Abbreviation used
to represent atom
in chemical
formulas

Atomic number
Number of protons
in atom

mass number → A
atomic number → Z

Atomic number

Element symbol

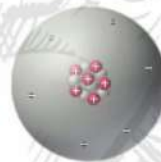
Element name

Atomic mass

Where:

- X** = element symbol
- A** = mass number
- Z** = atomic number

${}^{12}_6\text{C}$
6 protons
6 neutrons
6 electrons



Often, Z is omitted because it can be obtained from the periodic table.

Periodic Table of Elements

Atomic Mass

Periodic Table of Elements																		18
Atomic Mass																		
1	H																	He
2																		
3	Li																	Be
4	Be																	
5																		
6	B																	C
7	C																	N
8	N																	O
9	O																	F
10	F																	Ne
11	Na																	Mg
12	Mg																	
13																		
14	Al																	Si
15	Si																	P
16	P																	S
17	S																	Cl
18	Cl																	Ar
19	K																	Ca
20	Ca																	Sc
21	Sc																	Ti
22	Ti																	V
23	V																	Cr
24	Cr																	Mn
25	Mn																	Fe
26	Fe																	Co
27	Co																	Ni
28	Ni																	Cu
29	Cu																	Zn
30	Zn																	Ga
31	Ga																	Ge
32	Ge																	As
33	As																	Se
34	Se																	Br
35	Br																	Kr
36	Kr																	
37	Rb																	Sr
38	Sr																	Y
39	Y																	Zr
40	Zr																	Nb
41	Nb																	Mo
42	Mo																	Tc
43	Tc																	Ru
44	Ru																	Rh
45	Rh																	Pd
46	Pd																	Ag
47	Ag																	Cd
48	Cd																	In
49	In																	Sn
50	Sn																	Sb
51	Sb																	Te
52	Te																	I
53	I																	Xe
54	Xe																	
55	Cs																	Ba
56	Ba																	Hf
57	Hf																	Ta
58	Ta																	W
59	W																	Re
60	Re																	Os
61	Os																	Ir
62	Ir																	Pt
63	Pt																	Au
64	Au																	Hg
65	Hg																	Tl
66	Tl																	Pb
67	Pb																	Bi
68	Bi																	Po
69	Po																	At
70	At																	Rn
71	Rn																	
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The **number of neutrons (N)** in a nucleus is calculated using the mass number and the atomic number:

$$N = A - Z$$

Where:

- **N** = number of neutrons
- **A** = mass number (protons + neutrons)
- **Z** = atomic number (number of protons)

Example:



For sodium-23:

- **Mass Number A** = 23
- **Atomic Number Z** = 11 (protons 11)
- **Number of neutrons**

$$N = 23 - 11 = 12 \text{ Neutrons}$$

Example Table (Atomic Structure)

Element	Mass Number (A)	Atomic Number (Z)	Protons	Electrons	Neutrons (N)
${}_{8}^{16}\text{O}$	16	8	8	8	8
${}_{11}^{23}\text{Na}$	23	11	11	11	12
${}_{17}^{35}\text{Cl}$	35	17	17	17	18
${}_{20}^{40}\text{Ca}$	40	20	20	20	20

Atomic Structure – Check Your Understanding

Element	Mass Number (A)	Atomic Number (Z)	Protons	Electrons	Neutrons (N)
${}_{7}^{14}\text{N}$					
${}_{13}^{27}\text{Al}$					
${}_{15}^{31}\text{P}$					
${}_{19}^{39}\text{K}$					

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Nuclear Charge

The total nuclear charge equals the number of protons multiplied by the elementary charge:

$$\text{Nuclear charge} = +Ze$$

Where:

$$e = 1.6 \times 10^{-19} \text{ C}$$

Approximate Mass of the Nucleus

- The approximate mass of a nucleus is:

$$\text{Mass of nucleus} \approx A(u)$$

Size of the Nucleus

- From Rutherford experiments, the nuclear diameter is approximately: 10^{-14} m
- The atomic diameter is about **10,000 times larger** than the nuclear diameter.

Nuclear Density

- The nucleus has a very large density, reaching: $1.4 \times 10^{18} \text{ kg/m}^3$

لا تقارن نفسك بالآخرين ،

قارن نفسك بأهلك

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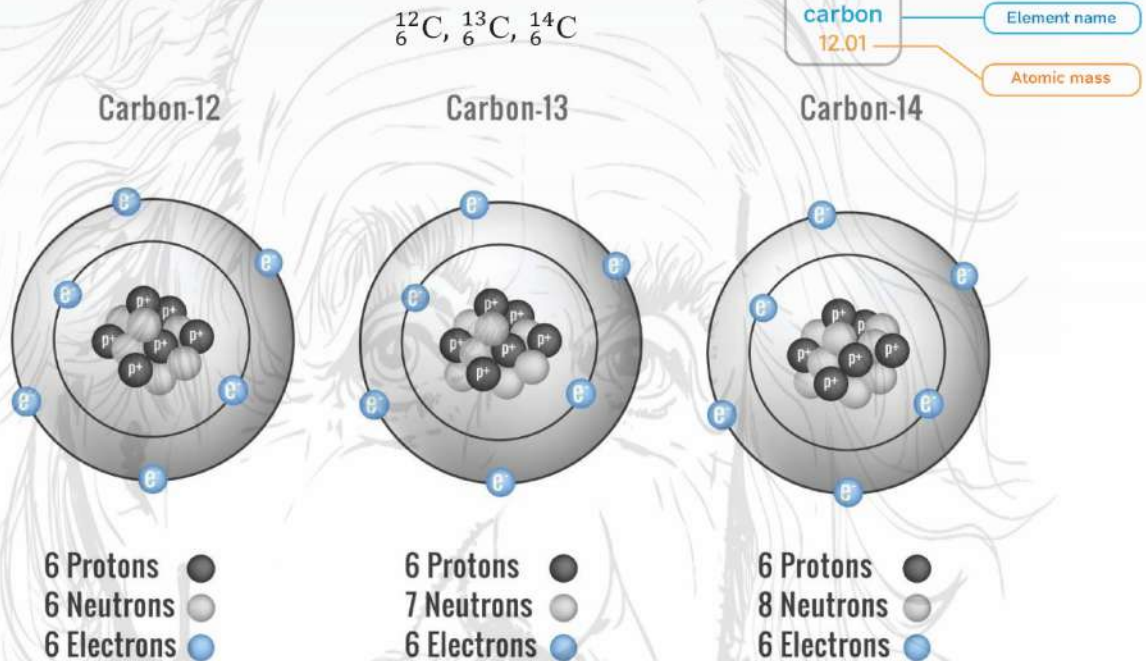
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Isotopes

Isotopes are atoms that have the **same number of protons** but **differ in the number of neutrons and the mass number**.

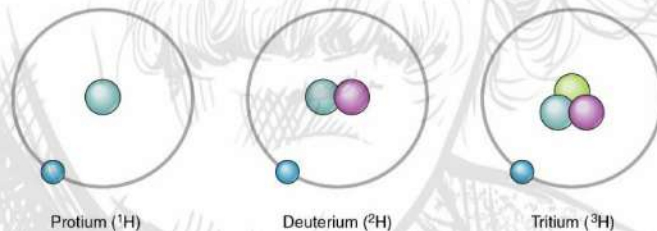
- Some isotopes are **natural** (such as uranium), while others are **artificial** (such as hydrogen isotopes).

Examples of Carbon Isotopes:

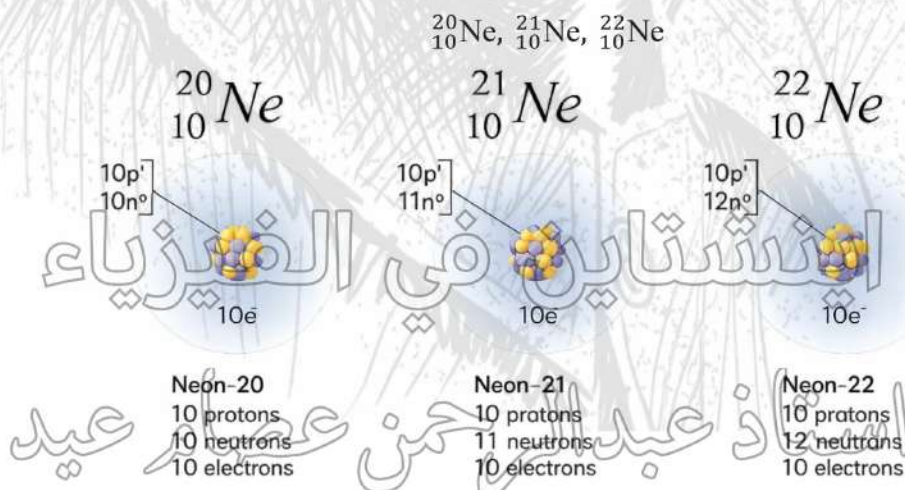


Hydrogen Isotopes:

- Hydrogen: ^1_1H
- Deuterium: ^2_1H
- Tritium: ^3_1H



The three naturally occurring **isotopes of neon** are:



Practice Exercises (Isotopes & Neutrons)

Exercise 1

The mass numbers of uranium isotopes are **235, 234, and 238**, and the atomic number of uranium is **92**.

Find the number of neutrons in each isotope.

$$N = A - Z$$

$${}_{92}^{235}\text{U}: N = 235 - 92 = 143$$

$${}_{92}^{234}\text{U}: N = 234 - 92 = 142$$

$${}_{92}^{238}\text{U}: N = 238 - 92 = 146$$

Find the number of neutrons in the mercury isotope ${}_{80}^{200}\text{Hg}$.

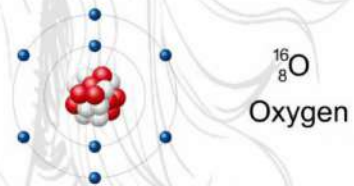
$$N = 200 - 80 = 120$$

Write the nuclear symbols of the three hydrogen isotopes that contain **0, 1, and 2** neutrons.

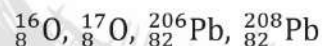
- 0 neutrons: ${}_1^1\text{H}$
- 1 neutron: ${}_1^2\text{H}$
- 2 neutrons: ${}_1^3\text{H}$

An isotope of **oxygen** has a **mass number of 16**.

How many **neutrons** are in the nucleus of this isotope?



For each of the following nuclei, determine the **atomic number (Z)**, **mass number (A)**, **number of neutrons (N)**, and **number of nucleons**. Then, record your answers in a table.



Nucleus	Atomic Number (Z)	Number of Neutrons (N)	Mass Number (A)	Number of Nucleons
${}_{8}^{16}\text{O}$				
${}_{8}^{17}\text{O}$				
${}_{82}^{206}\text{Pb}$				
${}_{82}^{208}\text{Pb}$				

The diagram shows an **oxygen atom** (${}_{8}^{16}\text{O}$).

Which of the following represents an **isotope** of the given atom?

- (a) ${}_{8}^{16}\text{X}$ (b) ${}_{16}^8\text{X}$ (c) ${}_{8}^{10}\text{X}$ (d) ${}_{8}^{18}\text{X}$



Average Atomic Mass

The **measured atomic mass** of an element is not usually a whole number. This is because most elements exist in nature as a **mixture of isotopes**.

- The atomic mass shown on the periodic table represents a **weighted average** of the masses of all naturally occurring isotopes.
- For example, the atomic mass of **chlorine** is **35.453 u**.
- This value is the weighted average of its two natural isotopes:

chlorine-35

chlorine-37

Although the mass of an individual atom is close to an integer mass number, the **average atomic mass** does not have to be an integer.

The isotope **carbon-12** is used as the standard for atomic masses:

$$1 \text{ u} = \frac{1}{12} \text{ of the mass of a carbon-12 atom}$$

The **strong nuclear force** is the force that binds nucleons together inside the nucleus.

Inside the nucleus, **two main forces act**:

- Electrostatic (electric) force**
- Strong nuclear force**

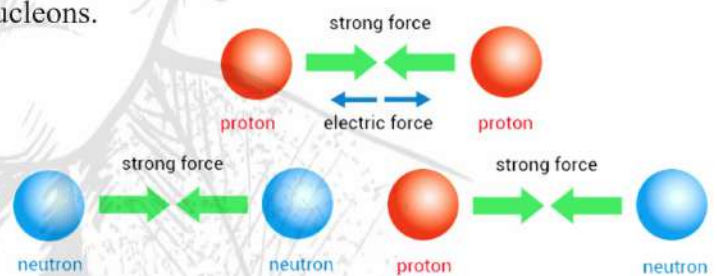
The Strong Nuclear Force

Electrons are held around the nucleus by the **electromagnetic force**.

However, **inside the nucleus, positively charged protons repel each other**.

The nucleus remains stable because an even stronger force acts between nucleons: the strong nuclear force.

- It is an **attractive force** acting between nucleons.
- It acts between:
 - ✓ proton-proton
 - ✓ neutron-neutron
 - ✓ proton-neutron
- It is more than **100 times stronger** than the electromagnetic force.
- It acts over a very short distance, about: $1.4 \times 10^{-15} \text{ m}$



Comparison of Forces Inside the Nucleus

Property	Electrostatic Force	Strong Nuclear Force
Depends on charge	Yes	No
Acts between	Protons only	All nucleons
Nature	Repulsive	Attractive
Range	Long range	Very short range
Increases with	Atomic number Z	Neutron number N

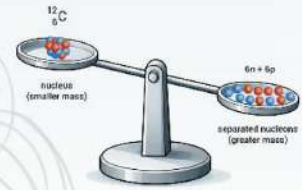


Mass Defect

Careful measurements show that the **mass of a nucleus** is **less than** the sum of the masses of its individual **protons and neutrons**.

The difference between these two values is called **the mass defect**:

The mass defect Δm can be calculated using the following relation:



$$\Delta m = (\text{mass of protons} + \text{mass of electrons} + \text{mass of neutrons}) - \text{mass of the atom}$$

$$\Delta m = (\text{sum of masses of nucleons}) - (\text{mass of nucleus})$$

This missing mass does not disappear; it is **converted into energy** according to Einstein's mass-energy equivalence.

Nuclear masses are measured accurately using **mass spectrometers**, and when calculating mass defect, the **mass of the electrons must be taken into account**.

The mass defect explains **why energy is released** when a nucleus is formed.

Mass Defect

The **mass defect** (Δm) is the **difference between the atomic mass and the sum of the masses of its constituents** (protons and neutrons).

The mass defect represents the **mass equivalent of the energy** that binds the nucleus together.

Mass Defect Formula

Where:

- A = mass number
- Z = atomic number
- $A - Z$ = number of neutrons
- m_{proton} = mass of a proton
- m_{neutron} = mass of a neutron
- m_{atom} = atomic mass
- Number of protons = Z
- Number of neutrons = $A - Z$

$$\Delta m = (\underbrace{Am_{\text{proton}}}_{\text{\# of protons}} + \underbrace{(A - Z)m_{\text{neutron}}}_{\text{\# of neutrons}}) - m_{\text{atom}}$$

Particle Masses

Particle	Mass (g)	Atomic Mass (amu)
Proton	1.67262×10^{-24}	1.00727
Neutron	1.67493×10^{-24}	1.00866
Electron	0.00091×10^{-24}	0.00055

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Mass Defect

The atomic mass of **helium-4** ${}^4_2\text{He}$ is **4.002603 u**.

A helium-4 nucleus consists of **two protons and two neutrons**.

Given that:

- Mass of hydrogen atom ${}^1_1\text{H} = 1.007825 \text{ u}$
- Mass of neutron $n = 1.008665 \text{ u}$

Calculate **the mass defect** of the helium-4 atom.

Solution

Step 1: Identify the number of nucleons

Helium-4 contains:

- 2 protons
- 2 neutrons

Step 2: Calculate the total mass of the separate nucleons

$$\text{Mass of 2 protons} = 2(1.007825) = 2.015650 \text{ u}$$

$$\text{Mass of 2 neutrons} = 2(1.008665) = 2.017330 \text{ u}$$

$$\text{Total mass of nucleons} = 4.032980 \text{ u}$$

Step 3: Use the measured atomic mass

$$\text{Mass of helium-4 atom} = 4.002603 \text{ u}$$

Step 4: Calculate the mass defect

$$\Delta m = (\text{mass of nucleons}) - (\text{mass of atom})$$

$$\Delta m = 4.032980 - 4.002603 = 0.030377 \text{ u}$$



The atomic mass of **oxygen-16** ${}^{16}_8\text{O}$ is **15.994915 u**.

An oxygen-16 nucleus consists of **eight protons and eight neutrons**.

Given that:

- Mass of hydrogen atom ${}^1_1\text{H} = 1.007825 \text{ u}$
- Mass of neutron $n = 1.008665 \text{ u}$

Calculate **the mass defect** of the oxygen-16 atom.

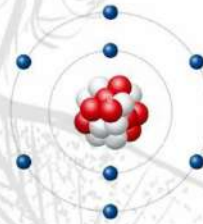
Solution

Step 1: Mass of separate nucleons

$$8(1.007825) + 8(1.008665) = 16.131920 \text{ u}$$

Step 2: Mass defect

$$\Delta m = 16.131920 - 15.994915 = 0.137005 \text{ u}$$



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The atomic mass of **deuterium** ${}^2_1\text{H}$ is measured experimentally to be **2.014102 u**.
A deuterium nucleus consists of **one proton and one neutron**.

Given that:

- Mass of hydrogen atom ${}^1_1\text{H} = 1.007825 \text{ u}$
- Mass of neutron $n = 1.008665 \text{ u}$

Calculate **the mass defect of the deuterium atom** and explain the meaning of the result.

Solution

Step 1: Identify the nucleon composition

Deuterium contains:

- 1 proton (taken as 1 hydrogen atom)
- 1 neutron

Step 2: Calculate the total mass of the separate nucleons

$$\text{Mass of nucleons} = 1.007825 + 1.008665 = 2.016490 \text{ u}$$

Step 3: Use the measured atomic mass

The **actual (true) mass of the deuterium atom**, obtained from experiments using a mass spectrometer, is: **2.014102 u**

Step 4: Calculate the mass defect

$$\Delta m = (\text{mass of nucleons}) - (\text{mass of atom})$$

$$\Delta m = 2.016490 - 2.014102 = 0.002388 \text{ u}$$

The atomic mass of **lithium-7** ${}^7_3\text{Li}$ is **7.016004 u**.

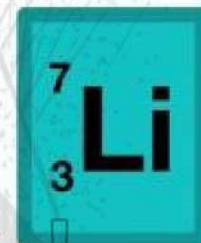
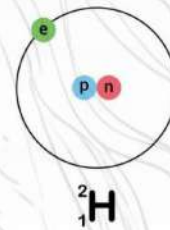
A lithium-7 nucleus consists of **three protons and four neutrons**.

Given that:

- Mass of hydrogen atom ${}^1_1\text{H} = 1.007825 \text{ u}$
- Mass of neutron $n = 1.008665 \text{ u}$

Calculate **the mass defect of the lithium-7 atom**.

Deuterium



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Binding Energy

Einstein showed that **mass and energy are equivalent**.

To remove a nucleon from a nucleus, **work must be done** to overcome the **strong nuclear force**, and this work adds energy to the system.

- A system of **separated protons and neutrons** has **more energy** than the same nucleons bound together in a nucleus.
- The **energy difference** between the separated nucleons and the assembled nucleus is called the **binding energy**.
- Since the assembled nucleus has **less energy**, the binding energy is considered **negative**.

Binding energy can also be defined as:

- The **energy required to completely separate** a nucleus into its individual nucleons.

The binding energy can be expressed using Einstein's equation: $E = mc^2$

Where:

$$\Delta m = (\text{sum of masses of nucleons}) - (\text{mass of nucleus})$$

Or:

$$\Delta m = (\text{mass of protons} + \text{mass of electrons} + \text{mass of neutrons}) - \text{mass of the atom}$$

$$\Delta m = Z M({}_1^1\text{H}) + N m_n - M({}_Z^AX)$$

After calculating Δm in atomic mass units:

$$E_{\text{bind}} = \Delta m \times 931.49 \text{ MeV}$$

- **The total mass** of separated nucleons is **greater** than **the mass of the nucleus**.
- Therefore, nuclear binding energy is always **negative**.

Energy Equivalent of Mass

The **energy equivalent of a mass** is given by:

$$E = mc^2$$



$$E = Mc^2$$

Where:

- m is the mass
- c is the speed of light in vacuum

Energy Units in Nuclear Physics

In nuclear physics, masses are usually measured in **atomic mass units (u)**:

$$1 u = 1.6605 \times 10^{-27} \text{ kg}$$

Using Einstein's equation:

$$E = (1.6605 \times 10^{-27})(3 \times 10^8)^2$$

$$E = 1.4924 \times 10^{-10} \text{ J}$$

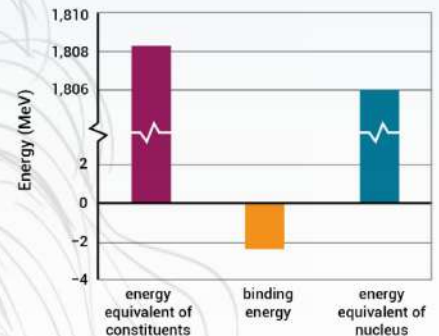
Since the **electron volt (eV)** is a convenient energy unit:

$$1 \text{ eV} = 1.60218 \times 10^{-19} \text{ J}$$

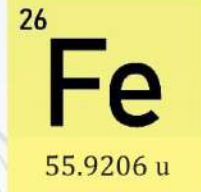
Therefore:

$$1 u = 931.49 \text{ MeV}$$

This conversion greatly simplifies calculations involving **mass defect** and **binding energy** in nuclear physics.



Determine the **binding energy** of an **iron nucleus** ${}^{56}_{26}\text{Fe}$ expressed in **electron volts (eV)** and **joules (J)**, given that the **nuclear mass** of iron is: 55.9206 u



- Mass of hydrogen atom = **1.007825 u**
- Mass of neutron = **1.008665 u**

Given

- Nuclear mass of iron nucleus = **55.9206 u**
- Atomic number $Z = 26$
- Mass number $A = 56$
- Mass of hydrogen atom = **1.007825 u**
- Mass of neutron = **1.008665 u**
- Energy equivalent:

$$1 \text{ u} = 931.49 \text{ MeV}$$

$$1 \text{ eV} = 1.60218 \times 10^{-19} \text{ J}$$

Step 1: Determine the number of nucleons

- Number of protons: $Z = 26$
- Number of neutrons: $N = A - Z = 56 - 26 = 30$

Step 2: Calculate the total mass of the separated nucleons

Mass of 26 hydrogen atoms (protons): $26 \times 1.007825 = 26.20345 \text{ u}$

Mass of 30 neutrons: $30 \times 1.008665 = 30.25995 \text{ u}$

Total mass of separated nucleons: $26.20345 + 30.25995 = 56.46340 \text{ u}$

Step 3: Calculate the mass defect

$$\Delta m = (\text{mass of separated nucleons}) - (\text{mass of nucleus})$$

$$\Delta m = 56.46340 - 55.9206 = 0.54280 \text{ u}$$

Step 4: Calculate the binding energy in MeV

$$E_b = \Delta m \times 931.49$$

$$E_b = 0.54280 \times 931.49 = 506 \text{ MeV}$$

Step 5: Convert the binding energy to joules

$$1 \text{ MeV} = 10^6 \times 1.6 \times 10^{-19} \text{ J}$$

$$E_b = 506 \times 1.6 \times 10^{-13} = 8.11 \times 10^{-11} \text{ J}$$

The mass of the tritium isotope ${}^3_1\text{H}$ is **3.016049 u**.

The mass of a hydrogen atom is **1.007825 u**, and the mass of a neutron is **1.008665 u**.

Given that:

$$1 u = 931.49 \text{ MeV}$$

(a) Calculate the **mass defect** of tritium.

(b) Calculate the **binding energy** of the tritium nucleus.

Solution

Step 1: Determine the constituents of tritium

Tritium nucleus consists of:

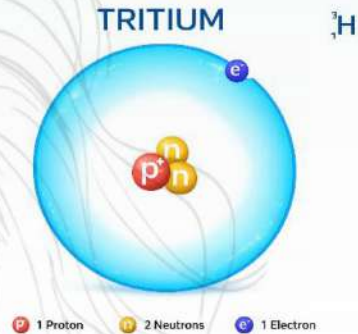
- 1 proton (included in hydrogen atom mass)
- 2 neutrons

Step 2: Calculate the total mass of the separated particles

Mass of 1 hydrogen atom: = 1.007825 u

Mass of 2 neutrons: = $2 \times 1.008665 = 2.017330 u$

Total mass of separated particles: = $1.007825 + 2.017330 = 3.025155 u$



Step 3: Calculate the mass defect

$$\Delta m = (\text{mass of separated particles}) - (\text{mass of nucleus})$$

$$\Delta m = 3.025155 - 3.016049 = 0.009106 u$$

Step 4: Calculate the binding energy

$$E_b = \Delta m \times 931.49$$

$$E_b = 0.009106 \times 931.49 = 8.48 \text{ MeV}$$

Since energy is released when the nucleus is formed: $E_b = -8.48 \text{ MeV}$

Calculate the **nuclear binding energy** of the copper isotope ${}^{63}_{29}\text{Cu}$ expressed in **electron volts (eV)** and **joules (J)**

Hint:

- Energy equivalent of one atomic mass unit: $1 u = 931.49 \text{ MeV}$
- Mass of a neutron: $m_n = 1.008665 u$
- Atomic mass of a hydrogen atom: $m({}^1_1\text{H}) = 1.007825 u$
- Atomic mass of copper-63: $m({}^{63}_{29}\text{Cu}) = 62.929598 u$

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Final Exam Moe

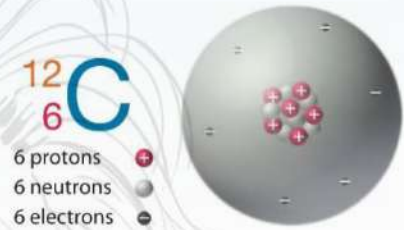
The mass of the carbon-12 nucleus $^{12}_6\text{C}$ is **12.000000 u**.

The mass of a hydrogen atom is **1.007825 u**, and the mass of a neutron is **1.008665 u**.

Given that: $1 \text{ u} = 931.49 \text{ MeV}$

(a) Calculate the **mass defect** of the carbon-12 nucleus.

(b) Calculate the **binding energy** of the nucleus.



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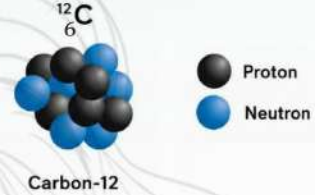
Step	Item	Calculation / Result	Marks
1	Identify nucleus constituents	$Z = 6 \text{ protons}, N = 6 \text{ neutrons}$	1
2	Mass of 6 hydrogen atoms	$6 \times 1.007825 = 6.046950 \text{ u}$	1
3	Mass of 6 neutrons	$6 \times 1.008665 = 6.051990 \text{ u}$	1
4	Total mass of separated particles	$6.046950 + 6.051990$	2
5	mass-defect formula	$\Delta m = (\text{mass of separated particles}) - (\text{mass of nucleus})$	1
6	Mass defect calculation	$\Delta m = 12.098940 - 12.000000$	1
7	Binding energy formula	$E_b = \Delta m \times 931.49$	1
8	Binding energy value	$E_b = 0.098940 \times 931.49 = 92.2 \text{ MeV}$	1
9	Binding energy sign	$E_b = -92.2 \text{ MeV}$	1
Total		10 / 10	

Use these values to solve the following problems:

- Mass of hydrogen atom = **1.007825 u**
- Mass of neutron = **1.008665 u**
- $1 u = 931.49 \text{ MeV}$

The carbon isotope $^{12}_6\text{C}$ has a mass of **12.000 u**.

- (a) Calculate the **mass defect** of the nucleus.
 (b) Calculate the **binding energy** of the nucleus.



Deuterium ^2_1H has a mass of **2.014102 u**.

- (a) Calculate the **mass defect** of the nucleus.
 (b) Calculate the **binding energy** of the nucleus.

The nitrogen isotope $^{15}_7\text{N}$ has a **mass defect of $-0.113986 u$** .

- (a) Calculate the **mass of this isotope**.
 (b) Calculate the **binding energy** of the nucleus.

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Use these values to solve the following problems:

- Mass of hydrogen atom = **1.007825 u**
- Mass of neutron = **1.008665 u**
- $1 u = 931.49 \text{ MeV}$

The oxygen isotope $^{16}_8\text{O}$ has a mass of **15.994915 u**.

- Determine the **mass defect** of the nucleus.
- Find the **binding energy** of the nucleus.

The magnesium isotope $^{24}_{12}\text{Mg}$ has a mass of **23.985042 u**.

- Calculate the **mass defect** of the nucleus.
- Calculate the **binding energy** of the nucleus.

The isotope $^{56}_{26}\text{Fe}$ has a mass of **55.934940 u**.

- Calculate the **mass defect** of the nucleus.
- Calculate the **binding energy** of the nucleus.
- State whether this nucleus is **stable or unstable**, giving a reason based on the binding energy.

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Average Binding Energy per Nucleon

The **average binding energy per nucleon** is the binding energy divided by the mass number:

$$\bar{E}_b = \frac{E_{\text{bind}}}{A}$$

- The **stability of a nucleus** depends on $\bar{E}_b$, not on the total binding energy.
- A larger value of average binding energy indicates a more stable nucleus.

The atomic mass of the magnesium nucleus is: $M({}_{12}^{23}\text{Mg}) = 22.994124 \text{ u}$ and the **sum of the masses of its free nucleons** is: $m_{\text{nucleons}} = 23.189215 \text{ u}$

Calculate:

1. The **energy required to completely separate all nucleons** of the magnesium nucleus.
2. The **average binding energy per nucleon**.

Given:

$$1 \text{ u} = 931.49 \text{ MeV}$$

Solution

Step 1: Calculate the mass defect

The mass defect is given by:

$$\Delta m = (\text{sum of masses of free nucleons}) - (\text{mass of nucleus})$$

$$\Delta m = 23.189215 - 22.994124 = 0.195091 \text{ u}$$

Step 2: Calculate the total nuclear binding energy

The binding energy is:

$$E_b = \Delta m \times 931.49$$

$$E_b = 0.195091 \times 931.49 = 181.7 \text{ MeV}$$

This represents the **energy required to separate all nucleons** of the nucleus.

Step 3: Calculate the average binding energy per nucleon

The mass number of magnesium: $A = 23$

$$\text{Average binding energy per nucleon} = \frac{E_b}{A} = \frac{181.7}{23} = 7.90 \text{ MeV}$$

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If the **binding energy per nucleon** in the sodium nucleus $^{23}_{11}\text{Na}$ is equal to **8.11 MeV**, calculate:

1. The **total nuclear binding energy** of the sodium nucleus.
2. The **mass defect corresponding to the binding energy** of the sodium nucleus.

Using the given data, calculate the **average nuclear binding energy per nucleon** of the bromine isotope $^{75}_{35}\text{Br}$ expressed in **MeV**.

Hint:

- Energy equivalent of one atomic mass unit: $1 u = 931.49 \text{ MeV}$
- Mass of a neutron: $m_n = 1.008665 u$
- Atomic mass of a hydrogen atom: $M(^1\text{H}) = 1.007825 u$
- Atomic mass of bromine-75: $M(^{75}_{35}\text{Br}) = 74.925776 u$



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Using the given data, calculate the **difference between the binding energies** of the two nuclei ${}^{23}_{11}\text{Na}$ and ${}^{23}_{12}\text{Mg}$ and **state the reason for this difference**. However, the fact that both nuclei have the **same mass number**.

Given:

- Energy equivalent of one atomic mass unit: $1\text{ u} = 931.49\text{ MeV}$
- Mass of a neutron: $m_n = 1.008665\text{ u}$
- Atomic mass of a hydrogen atom: $M({}^1\text{H}) = 1.007825\text{ u}$
- Atomic mass of magnesium-23: $M({}^{23}_{12}\text{Mg}) = 22.994124\text{ u}$
- Atomic mass of sodium-23: $M({}^{23}_{11}\text{Na}) = 22.989768\text{ u}$

Part (1): Binding Energy of ${}^{23}_{11}\text{Na}$

Step 1: Determine numbers of protons and neutrons

For sodium-23:

$$Z = 11, N = 23 - 11 = 12$$

Step 2: Mass of separated nucleons

$$\text{Mass of 11 hydrogen atoms} = 11 \times 1.007825 = 11.086075\text{ u}$$

$$\text{Mass of 12 neutrons} = 12 \times 1.008665 = 12.103980\text{ u}$$

$$\text{Total mass} = 11.086075 + 12.103980 = 23.190055\text{ u}$$

Step 3: Mass defect

$$\Delta m_{\text{Na}} = 23.190055 - 22.989768 = 0.200287\text{ u}$$

Step 4: Binding energy

$$E_{b,\text{Na}} = 0.200287 \times 931.49 = 186.6\text{ MeV}$$

Part (2): Binding Energy of ${}^{23}_{12}\text{Mg}$

Step 1: Determine numbers of protons and neutrons

$$Z = 12, N = 23 - 12 = 11$$

Step 2: Mass of separated nucleons

$$\text{Mass of 12 hydrogen atoms} = 12 \times 1.007825 = 12.093900\text{ u}$$

$$\text{Mass of 11 neutrons} = 11 \times 1.008665 = 11.095315\text{ u}$$

$$\text{Total mass} = 12.093900 + 11.095315 = 23.189215\text{ u}$$

Step 3: Mass defect

$$\Delta m_{\text{Mg}} = 23.189215 - 22.994124 = 0.195091\text{ u}$$

Step 4: Binding energy

$$E_{b,\text{Mg}} = 0.195091 \times 931.49 = 181.7\text{ MeV}$$

Part (3): Difference Between the Binding Energies

$$\Delta E_b = E_{b,\text{Na}} - E_{b,\text{Mg}}$$

$$\Delta E_b = 186.6 - 181.7 = 4.9\text{ MeV}$$

Part (4): Reason for the Difference

The **extra proton** in the nucleus of ${}^{23}_{12}\text{Mg}$ increases the **electrostatic repulsive force** between protons.

This stronger repulsion reduces the effectiveness of the **strong nuclear force**, resulting in a **lower binding energy**.

Therefore, the magnesium-23 nucleus is **less stable** and **easier to disintegrate** than a nucleus with fewer protons.

Relationship Between Binding Energy per Nucleon and Nuclear Stability

1. Binding Energy per Nucleon vs Mass Number

The **binding energy per nucleon** varies with the **mass number (A)** of the nucleus.

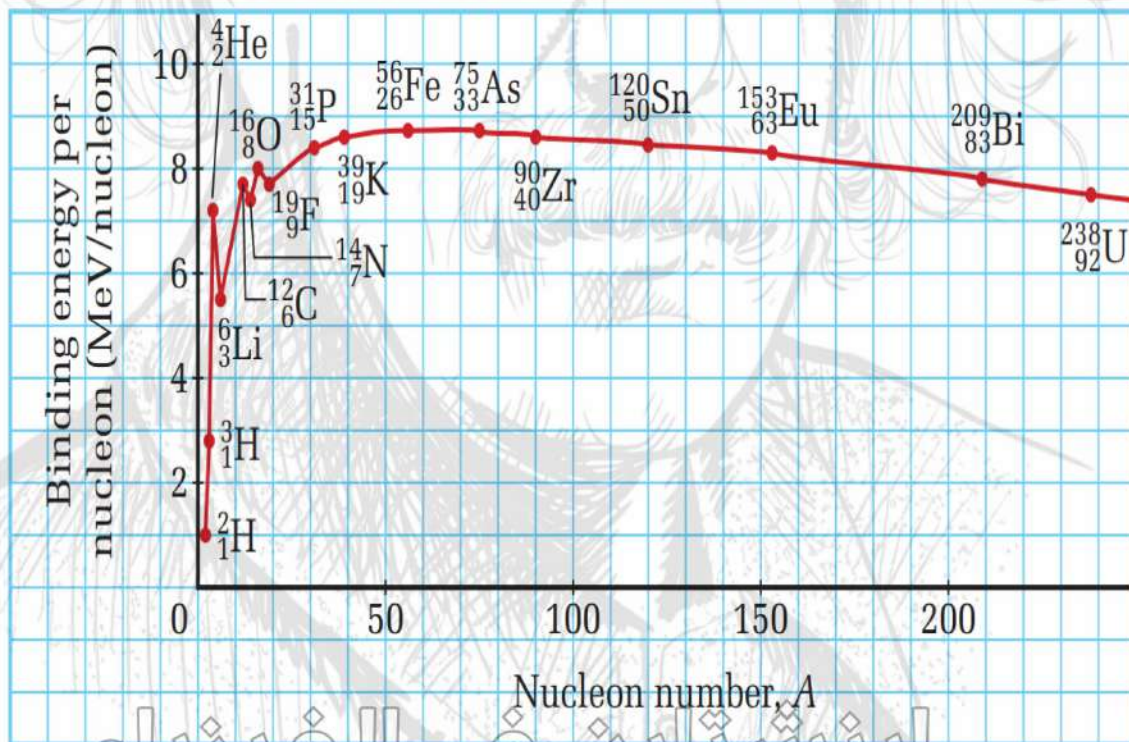
- For **light nuclei**, the binding energy per nucleon is relatively **small**.
- As the mass number increases, the binding energy per nucleon **increases rapidly**.
- The binding energy per nucleon reaches a **maximum value around iron-56**: ${}^{56}_{26}\text{Fe}$
- After this point, as the mass number increases further, the binding energy per nucleon **slowly decreases** for heavier nuclei such as uranium.

Conclusion:

Nuclei near **iron-56** are the **most stable nuclei**, since they have the **highest binding energy per nucleon**.

2. Stability of Nuclei Based on Mass Number

- **Light nuclei** ($A < 56$) can **release energy by fusion**, moving toward a higher binding energy per nucleon.
- **Heavy nuclei** ($A > 56$) can **release energy by fission**, also moving toward a higher binding energy per nucleon.
- Any nuclear reaction that moves a nucleus **closer to the peak at iron-56** releases energy naturally.



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Neutron-Proton Ratio and Nuclear Stability

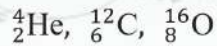
Nuclear stability also depends strongly on the **ratio of neutrons (N) to protons (Z)**.

(a) Light Nuclei ($Z \leq 20$)

- Stable when:

$$N \approx Z$$

- Examples of **stable nuclei**:



- Unstable when:

$$N < Z$$

due to increased electrostatic repulsion.

(b) Medium and Heavy Nuclei ($20 < Z < 83$)

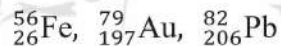
- Stable when:

$$N > Z$$

- Extra neutrons are needed to:

- ✓ Increase the **strong nuclear force**
- ✓ Reduce the effect of **electrostatic repulsion** between protons

- Examples of stable nuclei:



(c) Very Heavy Nuclei ($Z \geq 83$)

- Always unstable**, regardless of the number of neutrons.
- Examples:



- These nuclei undergo **radioactive decay** to reach greater stability.

4. Key Reasons for Nuclear Instability

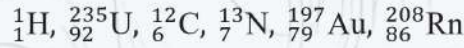
- Increasing the **number of protons** increases **electrostatic repulsion**.
- To maintain stability, the **number of neutrons must increase more rapidly than protons**.
- Beyond a certain atomic number, the strong nuclear force can no longer overcome proton repulsion.

Notes

- The **maximum binding energy per nucleon** occurs near **iron-56**.
- Nuclei are most stable when their binding energy per nucleon is **high**.
- Light nuclei stabilize when $N \approx Z$.
- Heavy nuclei require $N > Z$ for stability.
- Nuclei with $Z \geq 83$ are **always unstable**.

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For each of the following isotopes, determine whether the nucleus is **stable or unstable**, and **give a reason** for your answer:

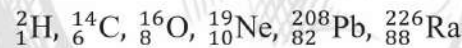


Stability of Selected Isotopes

Isotope	Stable / Unstable	Reason
${}^1_1\text{H}$	Stable	It contains only one proton in the nucleus, so there is no electrostatic repulsion between nucleons.
${}^{235}_{92}\text{U}$	Unstable	It is a very heavy element ($Z > 83$). No matter how many neutrons are present, the strong nuclear force cannot overcome the large electrostatic repulsion.
${}^{12}_6\text{C}$	Stable	It is a light nucleus ($Z < 20$) with equal numbers of protons and neutrons ($N = Z$), so nuclear forces are balanced.
${}^{13}_7\text{N}$	Unstable	It is a light nucleus ($Z < 20$) with $N < Z$, so the strong nuclear force is not sufficient to balance the electrostatic repulsion.
${}^{197}_{79}\text{Au}$	Stable	It is a heavy nucleus ($20 < Z < 83$) with $N > Z$, providing extra neutrons to reduce proton repulsion and increase stability.
${}^{208}_{86}\text{Rn}$	Unstable	It is a very heavy nucleus ($Z > 83$). Such nuclei are always unstable regardless of the number of neutrons.

Check your understanding

For each of the following isotopes, determine whether the nucleus is **stable or unstable**, and **give a reason** for your answer:



Isotope	Stable / Unstable	Reason
${}^2_1\text{H}$		
${}^{14}_6\text{C}$		
${}^{19}_{10}\text{Ne}$		
${}^{208}_{82}\text{Pb}$		
${}^{226}_{88}\text{Ra}$		

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Study the following table, then arrange the nuclei in **ascending order of stability**:

Nucleus	Mass Number (A)	Total Binding Energy, BE (MeV)	Binding Energy per Nucleon, BE/A (MeV)
${}^7_3\text{Li}$	7	39.24	5.606
${}^{62}_{28}\text{Ni}$	62	545.26	8.795
${}^{107}_{47}\text{Ag}$	107	915.26	8.554
${}^{206}_{82}\text{Pb}$	206	1622.32	7.875

(a) Arrange the given nuclei in **ascending order of stability**.

The nuclei arranged in **ascending order of stability** are:

$${}^7\text{Li} < {}^{206}\text{Pb} < {}^{107}\text{Ag} < {}^{62}\text{Ni}$$

(b) State the physical quantity used to compare the stability of nuclei, and explain briefly.

Nuclear stability is determined by the **binding energy per nucleon (BE/A)**.

$$\text{Ni} \left(\frac{BE}{A} \right) > \text{Ag} \left(\frac{BE}{A} \right) > \text{Pb} \left(\frac{BE}{A} \right) > \text{Li} \left(\frac{BE}{A} \right)$$

Therefore, nickel is the most stable nucleus, while lithium is the least stable.

Based on the adjacent diagram, which represents a part of the **curve of stability**, where each square represents a nucleus and the shaded squares represent **stable nuclei** while the dark squares represent **unstable nuclei**, answer the following questions:

(1) If the **total nuclear binding energy** of nucleus (X) is **186.3 MeV**, then the **binding energy per nucleon** for this nucleus equals:

- (a) 8.100 MeV (b) 15.50 MeV
(c) 16.94 MeV (d) 0.1200 MeV

Answer:

From the diagram:

- For nucleus (X):
Number of protons $Z = 11$
Number of neutrons $N = 12$
Mass number $A = Z + N = 23$

$$\text{Binding energy per nucleon} = \frac{\text{Total B.E}}{A} = \frac{186.3}{23} = 8.100 \text{ MeV}$$

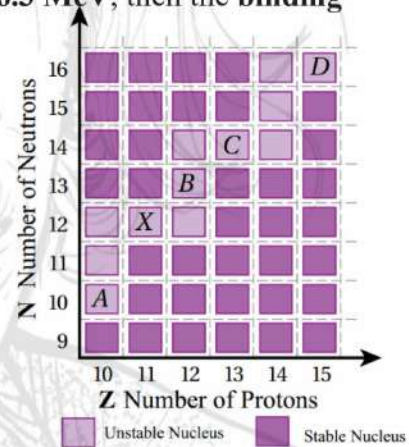
(2) Which nucleus has **more than one stable isotope** among the nuclei (A, X, C, D)?

- (a) A (b) X (c) C (d) D

Correct answer: C. (C)

Reason:

Nucleus (C) lies within a vertical column that contains **more than one stable nucleus** (same atomic number Z but different neutron numbers N), which indicates the presence of **multiple stable isotopes** for this element.



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The mass of the nucleus X is **7.014 amu**.

Using the graph shown, calculate the **binding energy per nucleon** of this nucleus.
(Given that 1 amu = 931.5 MeV).

- (a) 0.043 MeV (b) 39.6 MeV
(c) 5.71 MeV (d) 7.01 MeV

From the graph, the nucleus X has:

- Number of protons $Z = 3$
- Number of neutrons $N = 4$
- Mass number $A = 7$

Step (1): Calculate mass defect

$$\Delta m = (Zm_p + Nm_n) - M$$

$$\Delta m = (3 \times 1.00728 + 4 \times 1.00867) - 7.014$$

$$\Delta m = 0.04252 \text{ amu}$$

Step (2): Calculate total binding energy

$$\text{B.E} = \Delta m \times 931.5$$

$$\text{B.E} = 0.04252 \times 931.5 = 39.6 \text{ MeV}$$

Step (3): Calculate binding energy per nucleon

$$\frac{\text{B.E}}{A} = \frac{39.6}{7} = 5.71 \text{ MeV}$$

Correct answer: (B) 5.71 MeV

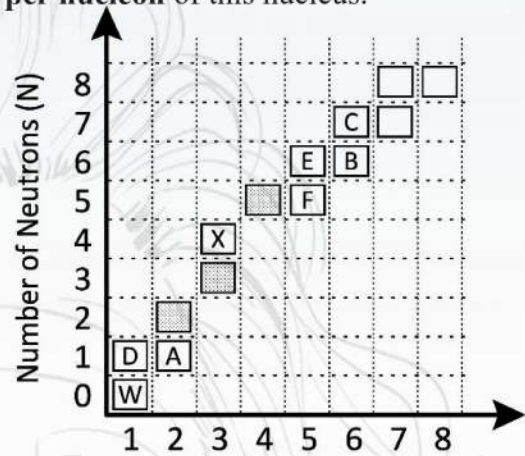
In the previous question, two nuclei represent **isotopes of the same element**.
Which of the following pairs represents these isotopes?

- (a) (A) and (D) (b) (E) and (F) (c) (C) and (E) (d) (B) and (E)

Correct answer: (B) (E) and (F)

Reason:

Isotopes have the **same atomic number (Z)** but **different mass numbers (A)**.

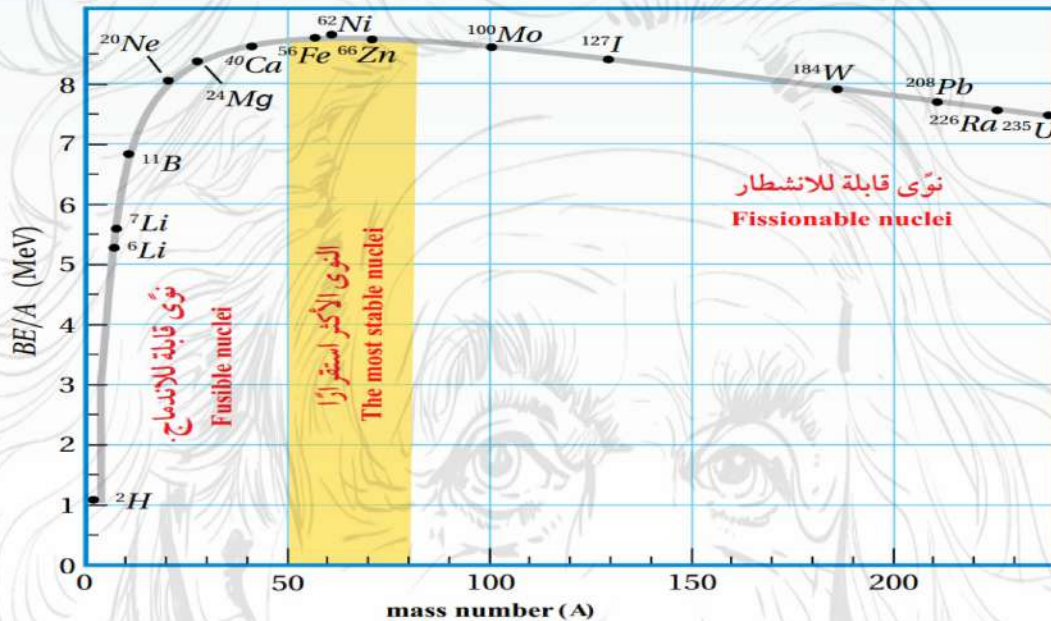


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Study the following graph of **binding energy per nucleon versus mass number**, then answer the following questions:

Note:

Nuclear stability is determined by **binding energy per nucleon (BE/A)**, not by the total binding energy (BE).



- Which nucleus is considered the **most stable**, and why?
- Which nuclei are more likely to undergo **nuclear fusion**, and which are more likely to undergo **nuclear fission**?
- Why do **light nuclei** become more stable after a fusion process?
- Why do **heavy nuclei** become more stable after a fission process?
- For which nuclei does the **binding energy per nucleon increase very slightly** with increasing mass number? Explain.

answer

(a)

The most stable nucleus is **iron (Fe)** (and nuclei near it such as nickel, Ni).

Reason:

Because iron has the **highest binding energy per nucleon**, which indicates maximum nuclear stability.

(b)

- **Heavy nuclei** such as **uranium (U)** and **radium (Ra)** are more likely to undergo **nuclear fission**.
- **Light nuclei** such as **hydrogen (H)** are more likely to undergo **nuclear fusion**.

(c)

Light nuclei become more stable after fusion because fusion forms a nucleus with a **higher binding energy per nucleon** than the original light nuclei.

(d)

Heavy nuclei become more stable after fission because fission produces medium-mass nuclei that have a **greater binding energy per nucleon** than the original heavy nucleus.

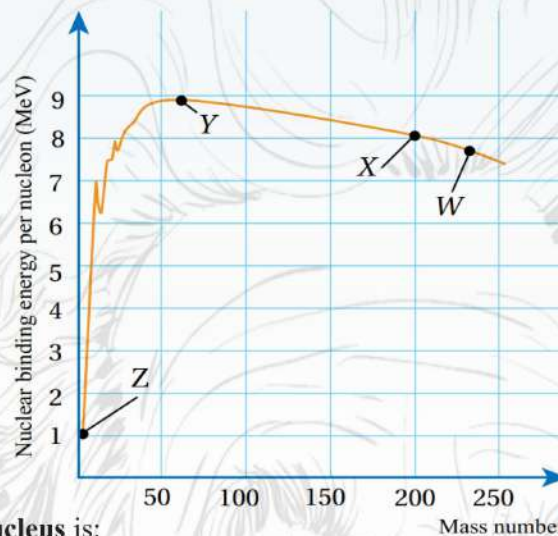
(e)

The binding energy per nucleon changes only slightly for **medium-mass nuclei** (around iron and nickel).

Explanation:

This is due to the **short-range nature of the nuclear force**, where each nucleon interacts only with nearby nucleons. This effect is known as **saturation of the nuclear force**.

Study the adjacent graph which shows the variation of **binding energy per nucleon (MeV)** with the **mass number (A)**, then answer the following questions (1, 2, 3 and 4):



(1) The **most stable nucleus** is:

- (a) (Z) (b) (Y) (c) (X) (d) (W)

Correct answer: B. (Y)

Reason:

The nucleus (Y) has the **highest binding energy per nucleon**, hence it is the most stable.

(2) The **total nuclear binding energy** of nucleus (X), in MeV, is:

- (a) 8 (b) 1600 (c) 200 (d) 208

Correct answer: B. 1600 MeV

Solution:

From the graph:

$$\left(\frac{BE}{A}\right)_X = 8 \text{ MeV}$$

and

$$A_X = 200$$

$$BE = \frac{BE}{A} \times A = 8 \times 200 = 1600 \text{ MeV}$$

(3) The nucleus that is **most likely to undergo nuclear fission** is:

- (a) (Z) (b) (Y) (c) (X) (d) (W)

Correct answer: D. (W)

Reason:

Heavy nuclei with large mass numbers are more likely to undergo **nuclear fission**.

(4) The nucleus that is **most likely to undergo nuclear fusion** is:

- (a) (Z) (b) (Y) (c) (X) (d) (W)

Correct answer: A. (Z)

Reason:

Light nuclei with small mass numbers are more likely to undergo **nuclear fusion** to form more stable nuclei.

For the nucleus ${}_{15}^{30}\text{P}$, the **nuclear binding energy** is **250.5 MeV**.

The total mass of its **separate nucleons** is **30.23925 amu**.

Calculate the **mass of the nucleus** ${}_{15}^{30}\text{P}$ in atomic mass units (amu).

(1 amu = 931.5 MeV)

The mass of the nucleus equals:

- A. 25.5555 amu
- B. 29.9706 amu
- C. 30.5 amu
- D. 31.76 amu

Step (1): Calculate the mass defect

$$\Delta m = \frac{\text{Binding Energy}}{931.5}$$

$$\Delta m = \frac{250.5}{931.5} = 0.2686 \text{ amu}$$

Step (2): Use the mass defect equation

$$\Delta m = (\text{Mass of nucleons}) - (\text{Mass of nucleus})$$

$$0.2686 = 30.23925 - M$$

Step (3): Calculate the nuclear mass

$$M = 30.23925 - 0.2686 = 29.9706 \text{ amu}$$

If the **difference between the mass of the nucleus and the total mass of its nucleons** in the nucleus

${}_{82}^{206}\text{Pb}$ is **1.7426 amu**, calculate the **binding energy per nucleon** of the lead nucleus.

The binding energy per nucleon equals:

- (a) 6.6 MeV
- (b) 7.8797 MeV
- (c) 8.876 MeV
- (d) 9.832 MeV

$$(1 \text{ amu} = 931.5 \text{ MeV})$$

Model Solution:

Step (1): Calculate the total binding energy

$$\text{Binding Energy (B.E)} = \Delta m \times 931.5$$

$$\text{B.E} = 1.7426 \times 931.5 = 1623.23 \text{ MeV}$$

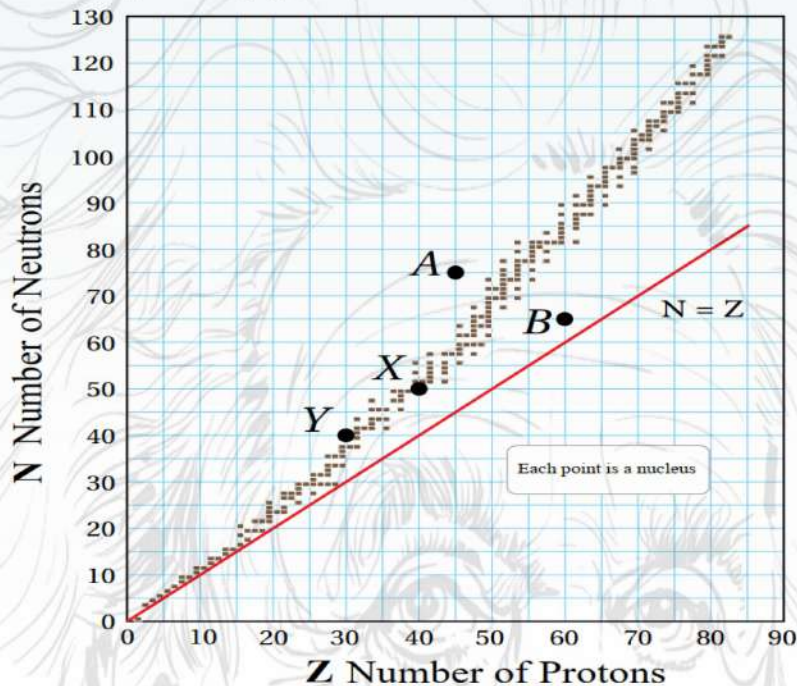
Step (2): Calculate the binding energy per nucleon

The mass number of lead is:

$$\frac{\text{B.E}}{A} = \frac{1623.23}{206} = 7.8797 \text{ MeV}$$

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Study the adjacent graph which shows the relationship between the **number of neutrons (N)** and the **number of protons (Z)** for different nuclei, then answer the following questions:



(1) Which of the following nuclei has the **highest binding energy per nucleon**?

- (a) (A) (b) (B) (c) (X) (d) (Y)

Correct answer: D. (Y)

Reason:

The nucleus (Y) lies closest to the **line of stability** in the region of medium-mass nuclei, which corresponds to the **maximum binding energy per nucleon**.

(2) Which of the following nuclei are **unstable nuclei**?

A. B. C. D.

- (a) (X, Y) (b) (B, A) (c) (A, X) (d) (B, Y)

Correct answer: B. (B, A)

Reason:

The unstable nuclei are those that lie **far from the line of stability** on the graph. Nuclei (A) and (B) deviate significantly from the stable region.

Note:

- Stable nuclei lie close to the **N = Z line** for light elements and above it for heavy elements.
- Nuclear stability is related to the **appropriate neutron-to-proton ratio** and the **binding energy per nucleon**.

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The following table shows the **total binding energy** of some nuclei.

Nucleus	Total Binding Energy (MeV)
${}^7_3\text{Li}$	39.24
${}^{62}_{28}\text{Ni}$	545.26
${}^{107}_{47}\text{Ag}$	915.26



Arrange the nuclei in **descending order of stability**.

- (a) $\text{Ni} > \text{Ag} > \text{Li}$ (b) $\text{Ag} > \text{Ni} > \text{Li}$ (c) $\text{Ni} < \text{Ag} < \text{Li}$ (d) $\text{Ag} = \text{Ni} = \text{Li}$

Correct answer: A

Reason:

Stability depends on **binding energy per nucleon (BE/A)**.

$$\text{Nucleus} \quad \text{BE/A (MeV)} \quad \text{Li} \quad \frac{39.24}{7} = 5.6 \quad \text{Ni} \quad \frac{545.26}{62} = 8.79 \quad \text{Ag} \quad \frac{915.26}{107} = 8.55$$

As the **number of nucleons in a nucleus increases**, the energy required to separate the nucleons:

- (a) Increases (b) Decreases (c) Remains constant (d) May increase or decrease

Correct answer: A

As the **binding energy per nucleon increases**, the **stability of the nucleus**:

- (a) Decreases (b) Increases (c) Does not change (d) The nuclear charge increases

Correct answer: B

A nucleus contains **3 protons and 4 neutrons**. If its total nuclear binding energy is **39.24 MeV**, calculate the **energy required to remove one nucleon**.

- (a) 12.08 MeV (b) 9.81 MeV (c) 5.60 MeV (d) 10.20 MeV

$$A = 3 + 4 = 7$$

$$\text{Energy per nucleon} = \frac{39.24}{7} = 5.60 \text{ MeV}$$

Correct answer: C

ابدأ من اليوم، ولا تنظر الوقت المثالي،
فالنجاح يبدأ بخطوة صغيرة.
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The number of neutrons in stable nuclei is usually:

- (a) Equal to the number of protons
- (b) Less than the number of protons
- (c) Slightly greater than the number of protons
- (d) Much greater than the number of protons

The neutron-to-proton ratio increases with increasing atomic number for a stable nucleus whose atomic number lies between:

- (a) $1 < Z \leq 20$
- (b) $56 < Z < 83$
- (c) $20 < Z < 43$
- (d) $20 < Z < 83$

A short-range attractive force that strongly binds nucleons together is known as:

- (a) Gravitational force
- (b) Electrostatic force
- (c) Nuclear force
- (d) Magnetic force

Which of the following nuclei is the least stable?

- (a) ${}^1_7\text{N}$
- (b) ${}^{234}_{90}\text{Th}$
- (c) ${}^{23}_{11}\text{Na}$
- (d) ${}^{90}_{40}\text{Zr}$

Which of the following is **NOT** a property of the nuclear force?

- (a) Very strong
- (b) Acts only between charged particles
- (c) Very short range
- (d) Does not distinguish between protons and neutrons

Most nuclei of elements are characterized by the fact that their density is:

- (a) Nearly constant
- (b) Nearly constant in volume
- (c) Nearly constant in mass
- (d) Variable

The number of neutrons in stable nuclei is:

- (a) Greater than the number of protons for light nuclei
- (b) Equal to the number of protons for light nuclei
- (c) Equal to the number of protons for medium nuclei
- (d) Less than the number of protons for heavy nuclei

Which of the following correctly describes the stable nuclides ${}^{63}_{29}\text{X}$ and ${}^{67}_{33}\text{Y}$?

- (a) $Z_Y = Z_X$
- (b) $N_Y = N_X$
- (c) $N_Y > N_X$
- (d) $N_Y < N_X$

Which of the following represents an isotope of the element ${}^{234}_{92}\text{X}$?

- (a) ${}^{192}_{91}\text{D}$
- (b) ${}^{192}_{90}\text{C}$
- (c) ${}^{235}_{92}\text{B}$
- (d) ${}^{234}_{90}\text{A}$

All nuclei with atomic number $Z > 82$ are described as:

- (a) Unstable (b) Having a neutron-to-proton ratio $\left(\frac{N}{Z}\right) = 1$
 (c) Stable (d) Having a neutron-to-proton ratio $\left(\frac{N}{Z}\right) < 1$

Isotopes of the same element are similar in:

- (a) Mass number (b) Atomic number and physical properties
 (c) Physical properties (d) Atomic number and chemical properties

The force between protons inside the nucleus is:

- (a) Nuclear attraction (b) Nuclear attraction and electrostatic repulsion
 (c) Electrostatic repulsion (d) Electrostatic attraction

In elements whose atomic number is less than (20), the neutron-to-proton ratio $\frac{N}{Z}$ is:

- (a) Equal to (1) (b) Less than (1)
 (c) Greater than (1) (d) All of the above

To make the unstable nucleus ${}^8_3X$ stable, we should:

- (a) Add 7 protons (b) Remove 2 neutrons
 (c) Add one neutron (d) Remove 3 neutrons

The number of neutrons in stable heavy nuclei is:

- (a) Greater than the number of protons (b) Less than the number of protons
 (c) Much less than the number of protons (d) Equal to the number of protons

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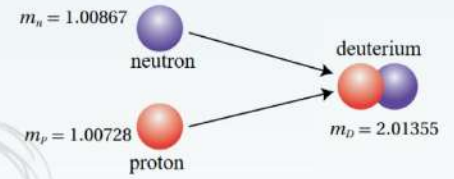
The deuterium nucleus ${}^2_1\text{H}(D)$ is formed from a proton and a neutron.

The following data are given:

Given

Quantity	Proton m_p	Neutron m_n	Deuterium nucleus m_D
Mass (amu)	1.00728	1.00867	2.01355

$$1 \text{ amu} = 931.5 \text{ MeV}$$



Calculate:

1. The mass defect (Δm)
2. The binding energy of the deuterium nucleus

Solution:

Step (1): Calculate the mass defect

$$\begin{aligned}\Delta m &= (m_p + m_n) - m_D \\ \Delta m &= (1.00728 + 1.00867) - 2.01355 \\ \Delta m &= 2.01595 - 2.01355 = 0.00240 \text{ amu}\end{aligned}$$

Step (2): Calculate the binding energy

$$\begin{aligned}\text{B.E} &= \Delta m \times 931.5 \\ \text{B.E} &= 0.00240 \times 931.5 = 2.24 \text{ MeV}\end{aligned}$$

الفيزياء لا تطلب منك
أن تكون
عبقرياً،

أينشتاين بل أن تكون الفيزياء
صبوراً ومثابراً

استاذ عبدالرحمن عصام عيّد

If the mass defect between the nucleus and its constituents of the nucleus ${}_{82}^{208}\text{Pb}$ is:

$$\Delta m = 2.90 \times 10^{-27} \text{ kg}$$

Calculate the **nuclear binding energy** of the nucleus in:

1. **Joules (J)**
2. **Mega electron volts (MeV)**

Given:

$$\Delta m = 2.90 \times 10^{-27} \text{ kg}$$

$$c = 3.0 \times 10^8 \text{ m/s}$$

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

Required:

- Binding energy (B.E) in J
- Binding energy (B.E) in MeV

Solution:

Step (1): Calculate the binding energy in joules

$$\text{B.E} = \Delta mc^2$$

$$\text{B.E} = 2.90 \times 10^{-27} \times (3.0 \times 10^8)^2$$

$$\text{B.E} = 2.6 \times 10^{-10} \text{ J}$$

Step (2): Convert the energy from joules to mega electron volts

$$\text{B.E} = \frac{2.6 \times 10^{-10}}{1.6 \times 10^{-19}} = 1.6 \times 10^9 \text{ eV}$$

$$\text{B.E} = 1600 \text{ MeV}$$

لا تقارن نفسك بالآخرين

قارن نفسك بنفسك كل يوم

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