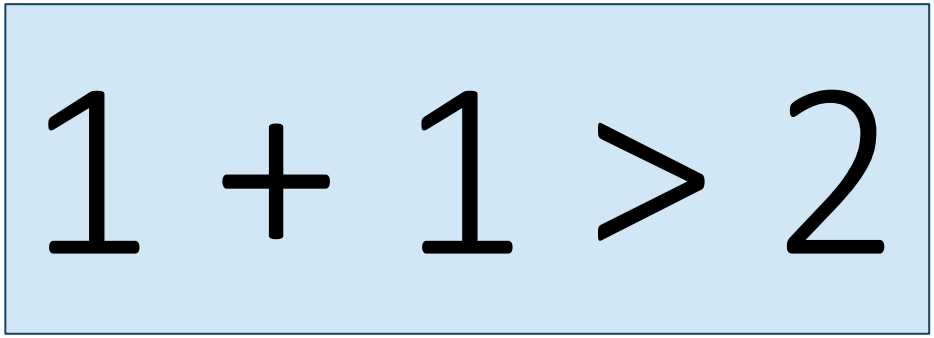


Energy and Mass Defects

IB PHYSICS | ATOMIC PHYSICS

Unified Atomic Mass Unit

When measuring and reporting the mass of individual atoms and subatomic particles, kilograms are inconveniently large…

The **unified atomic mass unit** is defined as one-twelfth of the mass of an isolated carbon-12 atom

1 mole of Carbon Atoms = 0.012 kg

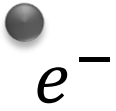
1 u =

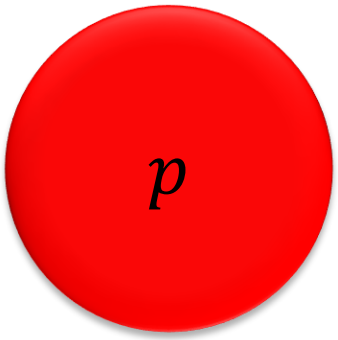
Unified Atomic Mass Unit

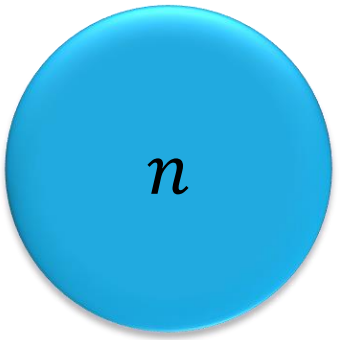
Electron (m_e)	9.110×10^{-31} kg	0.000549 u
Proton (m_p)	1.673×10^{-27} kg	1.007276 u
Neutron (m_n)	1.675×10^{-27} kg	1.008665 u

Unified atomic mass unit	1.661×10^{-27} kg

This is the only time that we will ever use 7 sig figs. In this case, rounding to 1.01 u just wouldn't cut it…





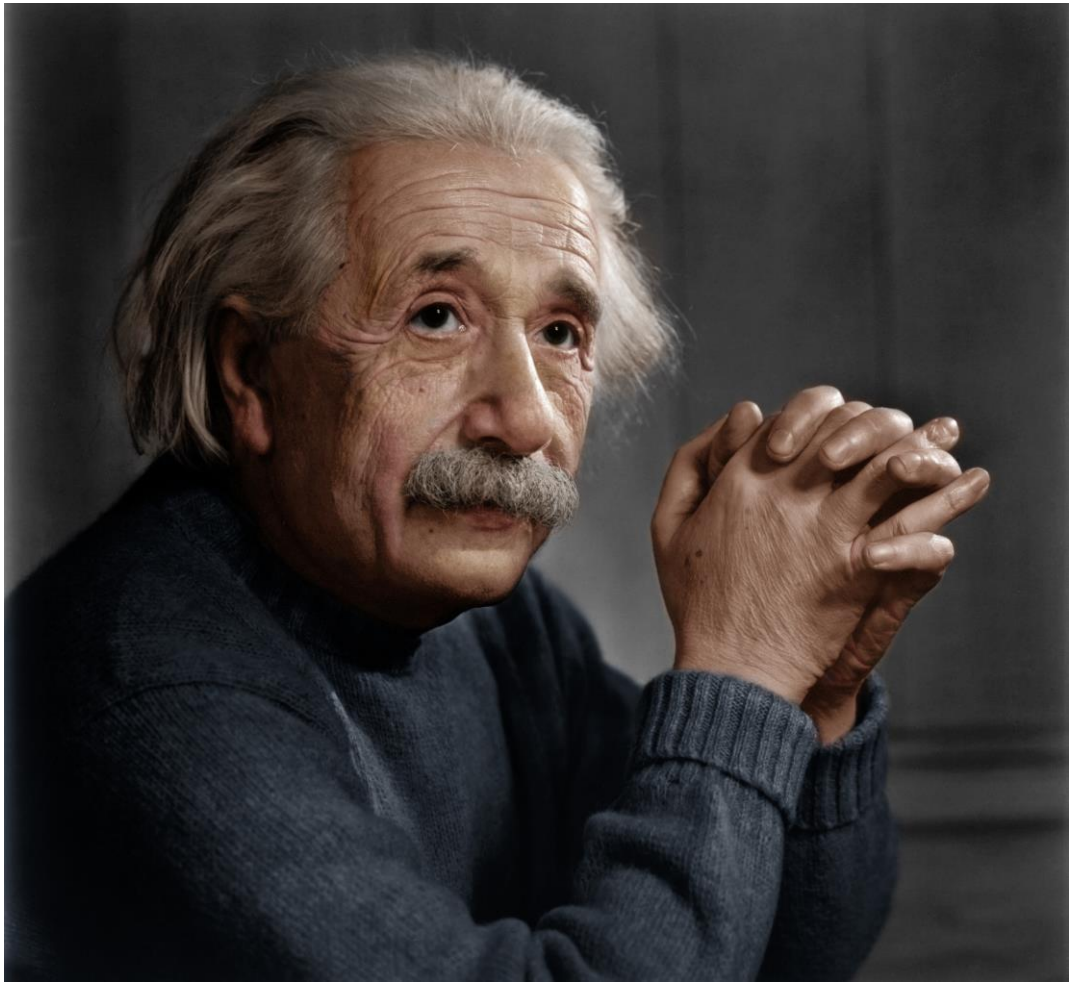


IB Physics Data Booklet

Fundamental constants

Quantity	Symbol	Approximate value
Speed of light in vacuum	c	$3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck's constant	h	$6.63 \times 10^{-34}\,\mathrm{J\,s}$
Elementary charge	e	$1.60 \times 10^{-19}\,\mathrm{C}$
Electron rest mass	m_e	$9.110 \times 10^{-31}\,\mathrm{kg} = 0.000549\,\mathrm{u} = 0.511\,\mathrm{MeV\,c^{-2}}$
Proton rest mass	m_p	$1.673 \times 10^{-27}\,\mathrm{kg} = 1.007276\,\mathrm{u} = 938\,\mathrm{MeV\,c^{-2}}$
Neutron rest mass	m_n	$1.675 \times 10^{-27}\,\mathrm{kg} = 1.008665\,\mathrm{u} = 940\,\mathrm{MeV\,c^{-2}}$
Unified atomic mass unit	u	$1.661 \times 10^{-27}\,\mathrm{kg} = 931.5\,\mathrm{MeV\,c^{-2}}$
Solar constant	S	$1.36 \times 10^{3}\,\mathrm{W\,m^{-2}}$
Fermi radius	R_0	$1.20 \times 10^{-15}\,\mathrm{m}$

Einstein's Famous Equation



According to Albert Einstein, *"mass and energy are different manifestations of the same things"*

Einstein's Famous Equation

$$E = mc^2$$

What is the energy equivalence of 1 g of matter?

IB Physics Data Booklet

Sub-topic 7.1 – Discrete energy and radioactivity	Sub-topic 7.2 – Nuclear reactions
$E = hf$ $\lambda = \frac{hc}{E}$	$\Delta E = \Delta m\, c^2$

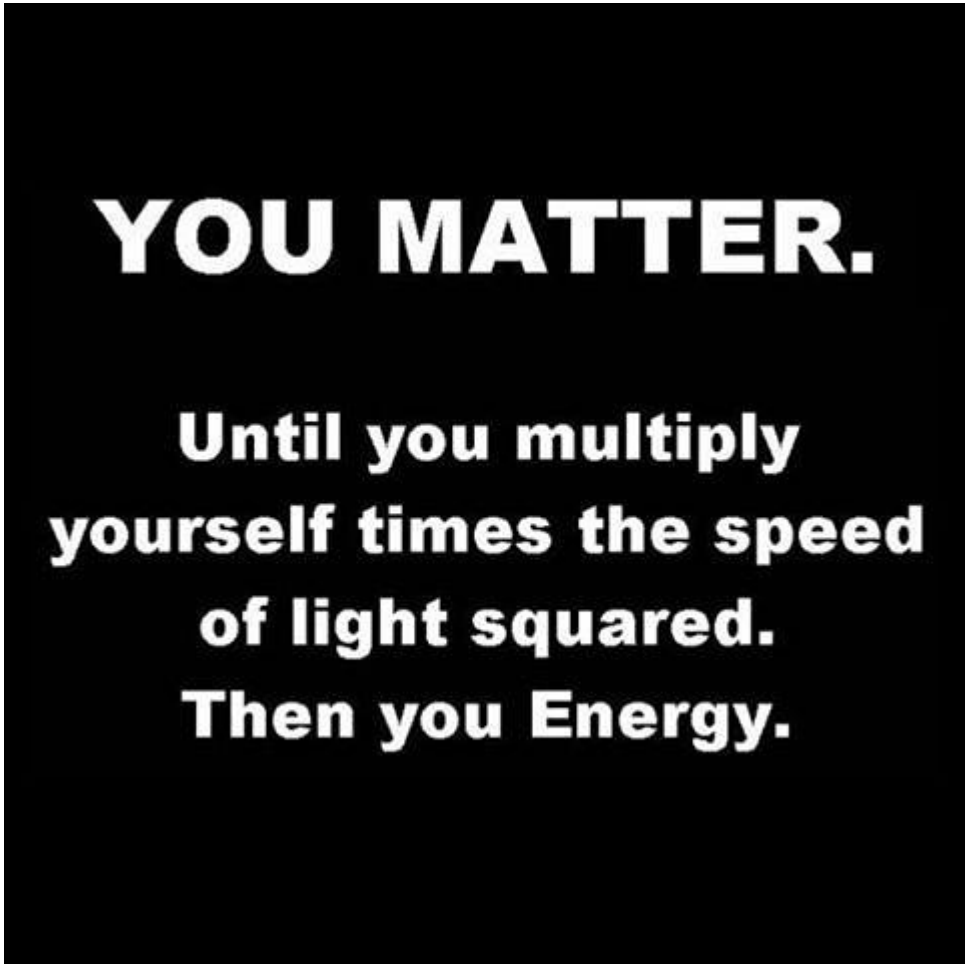
Sub-topic 7.3 – The structure of matter

Charge	Quarks			Baryon number
$\frac{2}{3}e$	u	c	t	$\frac{1}{3}$
$-\frac{1}{3}e$	d	s	b	$\frac{1}{3}$
All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of –1				

Charge	Leptons		
–1	e	μ	τ
0	υ_e	υ_μ	υ_τ
All leptons have a lepton number of 1 and antileptons have a lepton number of –1			

	Gravitational	Weak	Electromagnetic	Strong
Particles experiencing	All	Quarks, leptons	Charged	Quarks, gluons
Particles mediating	Graviton	W^+, W^-, Z^0	γ	Gluons

$E = mc^2$


YOU MATTER.
Until you multiply
yourself times the speed
of light squared.
Then you Energy.

New Unit for Energy!

Electron-Volt	eV
1 MeV = 10^6 eV	

$$\{Energy\ in\ eV\} = \frac{\{Energy\ in\ J\}}{1.60 \times 10^{-19}}$$

What is the energy equivalence of 1 proton (1.673×10^{-27} kg)?

New Unit for Mass

$$E = mc^2$$

$$m = \frac{E}{c^2} =$$

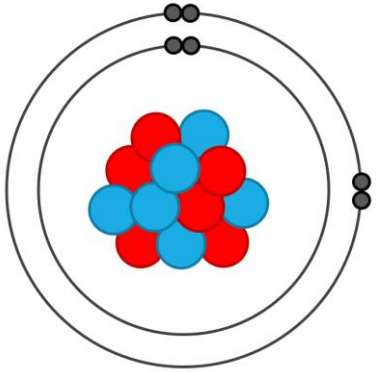
Unified Atomic Mass Unit

Electron rest mass (m_e)	9.110×10^{-31} kg	0.000549 u	0.511 MeV c^{-2}
Proton rest mass (m_p)	1.673×10^{-27} kg	1.007276 u	938 MeV c^{-2}
Neutron rest mass (m_n)	1.675×10^{-27} kg	1.008665 u	940 MeV c^{-2}
Unified atomic mass unit	1.661×10^{-27} kg	1.000000 u	931.5 MeV c^{-2}

Mass of the Nucleus

A neutral Carbon-12 atom contains:

6 protons
6 neutrons
6 electrons



Electron rest mass (m_e)	0.000549 u
Proton rest mass (m_p)	1.007276 u
Neutron rest mass (m_n)	1.008665 u
Unified atomic mass unit	1.000000 u

If the mass of Carbon-12 is defined as exactly 12.00000*u*, then the nucleus mass is:

$$12.00000\text{u} - (6 \times 0.000549\text{u}) = \mathbf{11.996706u}$$

Component Mass

A nucleus of Carbon-12 contains:

6 protons
6 neutrons

What is the total mass in terms of u?

Electron rest mass (m_e)	0.000549 u
Proton rest mass (m_p)	1.007276 u
Neutron rest mass (m_n)	1.008665 u

Unified atomic mass unit	1.000000 u

Mass Defect | 1+1 > 2

Mass sum of the Carbon-12 subatomic particles:

$$(6 \times 1.007276\text{u}) + (6 \times 1.008665\text{u}) = 12.095646\text{u}$$

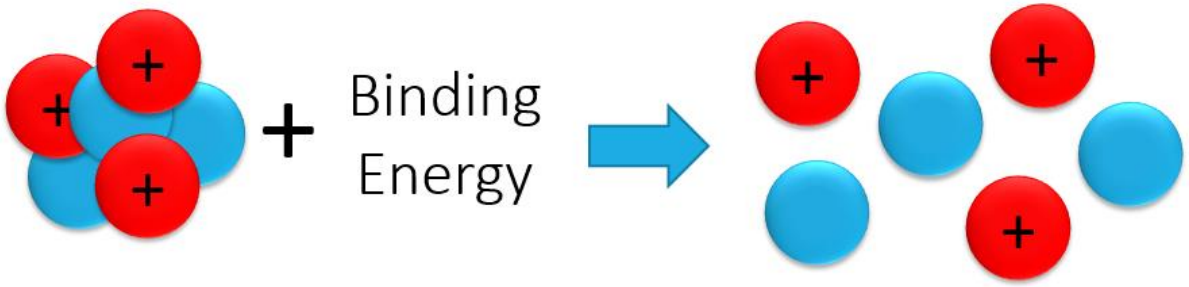
Mass of Carbon-12 nucleus: 11.996706u

Mass Defect → $12.095646\text{u} - 11.99670\text{u} = \mathbf{0.098946u}$

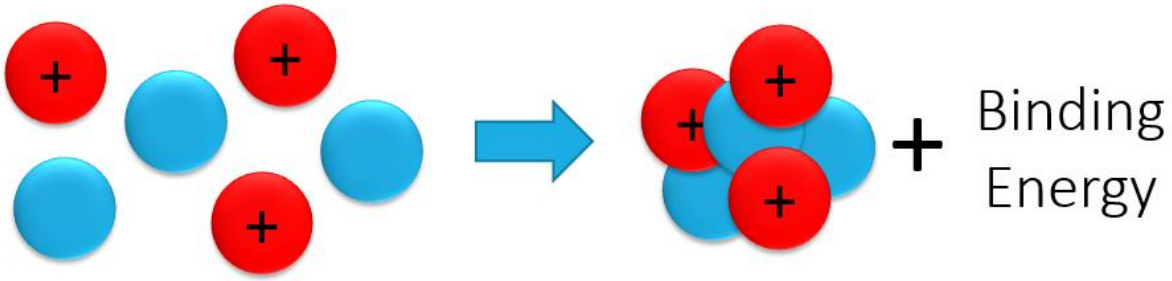
Where did the mass go?

Binding Energy

Binding Energy is the energy required to separate all of the nucleons



…or the energy released when a nucleus is formed from its nucleons



Mass Defect → Binding Energy

Unified atomic mass unit	1.661×10^{-27} kg	1.000000 u	931.5 MeV c^{-2}

$$\mathbf{0.098946u}$$

$$E = mc^2$$

Binding Energy per Nucleon

Binding Energy for Carbon-12 = 92.2 MeV

Number of Nucleons
for Carbon-12 =

6 protons
6 neutrons

Binding Energy per Nucleon =

Calculate Binding Energy per Nucleon

Nuclide	# of p	# of n	Nucleus Mass
Iodine-127	53		126.87544u

m_e	0.000549u
m_p	1.007276u
m_n	1.008665u
1u	931.5 MeV c^{-2}

Calculate Binding Energy per Nucleon

*For your assigned nuclide, calculate the binding energy per Nucleon and record data in shared spreadsheet

Use a periodic table to determine atomic # for your element

m_e	0.000549u
m_p	1.007276u
m_n	1.008665u
1u	931.5 MeV c^{-2}

	Element	Nucleus Mass (u)
1	Hydrogen-2	2.013553
2	Helium-3	3.014931
3	Hydrogen-3	3.015500
4	Helium-4	4.001505
5	Lithium-6	6.013476
6	Lithium-7	7.014356
7	Beryllium-9	9.009987
8	Carbon-12	11.996706
9	Nitrogen-14	13.999231
10	Oxygen-16	15.990523
11	Fluorine-19	18.993462
12	Magnesium-24	23.978454
13	Phosphorus-31	30.965527
14	Sulfur-34	33.959083
15	Potassium-39	38.953275

	Element	Nucleus Mass (u)
16	Iron-56	55.920662
17	Arsenic-75	74.903478
18	Krypton-84	83.891734
19	Zirconium-90	89.882739
20	Silver-107	106.879287
21	Tin-120	119.874752
22	Iodine-127	126.875373
23	Cesium-140	139.873608
24	Europium-153	152.886650
25	Tungsten-184	183.910307
26	Gold-197	196.923199
27	Lead-206	205.929447
28	Bismuth-209	208.934833
29	Uranium-235	234.993420
30	Uranium-238	238.000282

Blank Slide for Calculations ☺