The Nucleus

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**Description of the Nucleus**

•

Atoms consist of a dense, positively charged nucleus that is surrounded by

an electron cloud.

•

The nucleus contains positively charged protons and uncharged neutrons.

Protons and neutrons are collectively referred to as

**nucleons.**

•

The number of protons is the

**atomic number**

(

*Z*

).

•

The number of nucleons is the

**mass number**

(

*A*

).

•

The mass of a proton

or

neutron

is about 1 atomic

mass

unit (u). An

**atomic**

**mass**

**unit**

is a unit of

mass

equal to

1.66

×

10

−

27

kg.



***Review vocabulary:***

**Nucleus** – the tiny, massive, positively charged central core of an atom.

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**Description of the Nucleus**

•

The total charge on the nucleus is equal to the atomic number times the

fundamental charge.

•

The mass of the nucleus is approximately equal to the mass number times 1

atomic mass unit.

nuclear charge =

*Z*

e

nuclear mass

*A*

u

|  |
| --- |
| **Isotopes*** Recall that an element can have more than one isotope. That is, atoms of an element can have different masses.
* All nuclei of an element have the same number of protons but can have different numbers of neutrons.
* All isotopes of a neutral element have the same number of electrons as protons and behave chemically in the same way.
* A special method of notation is used to describe an isotope.

Mass number *A**X* Element symbol*Z*Atomic number*Copyright © McGraw-Hill Education* The Nucleus |

***Q: Compare and contrast the isotopes of carbon-12 and carbon-14.***

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**Isotopes**

•

Most elements have several isotopic forms that occur naturally.

•

The atomic mass listed in the periodic table is weighted average mass

of the naturally occurring isotopes of the element.

•

While the mass of an individual atom is close to a whole number of

mass units, the atomic mass determined from an average sample of

atoms does not have to be.

•

The mass of the isotope carbon

-

 is now used to define the mass unit.

12

One u is defined to be 1/12 the mass of the carbon

-

 isotope

12

.



***Q: Identify the mass number and the electric charge of each Hydrogen nucleus in the slide above.***

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**The Strong Nuclear Force**

•

The protons in the nucleus repel each other, but the

nucleus does not fly apart because an even stronger

attractive force exists within the nucleus.

•

The

**strong nuclear force**

is an attractive force

between nucleons that are close together, as they are

in a nucleus. It is the strongest of the four

fundamental forces.

•

The strong force has a range on the order of 10

−15

m.

Outside this range, the effects of the strong force are

minimal.

•

The strong nuclear force has the same strength

between all nucleon

pairs

but does not

affect

electrons.

•

The strong force is also responsible for holding

together the particles that make up protons and

neutrons.



The strong force is the same between all pairs of nucleons.

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**The Strong Nuclear Force**

•

The mass of an assembled nucleus is less

than

the

sum of the masses of the protons

and

neutrons

that compose it.

•

This difference between the sum of the

masses

of

the individual nucleons and the

actual mass

is

called the

**mass defect.**

•

To

pull a nucleon out of a nucleus, you

have to

do

work to overcome the strong

nuclear force.

•

Doing work adds energy to the

system and

so the system

of separated protons and

neutrons has

more

energy than the

assembled nucleus.

•

This energy difference between separated

nucleons and the assembled nucleus is

the

**binding energy**

of the nucleus

.



The energy equivalent of the mass of the individual nucleons is equal to the energy equivalent of the mass of the bound nucleus plus the binding energy.

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**The Strong Nuclear Force**

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Because the assembled nucleus has less

energy, all binding energies are negative.

•

The binding energy can be expressed in the

form of an equivalent amount of mass,

according to Einstein’s famous equation.

•

At this scale, the most convenient unit of

mass is the atomic mass unit

= 1.6605

(1

 u

×

10

−27

kg

)

 and the most

convenient

of energy is the electron volt

(1

eV

= 1.60218

×

10

−19

J).

•

The

energy equivalent of 1

u is 931.49 MeV.

2

c

*E m*



**Energy Equivalent of Mass**

***Q: Describe the meaning of the equation E = 931.49 MeV/u, and explain why it is important.***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **The Strong Nuclear Force***Use with Example Problem 1.***Problem** Use the information in the table below to compare the mass defect and binding energy of deuterium, 21 , with that of helium, 2 e.

|  |
| --- |
| **KnownMasses** |
| *m*hydrogen atom | 1.007825 u |
| *m*neutron | 1.008665 u |
| *m*deuterium atom | 2.014102 u |
| *m*helium atom | 4.002603 u |

**Response***SKETCH AND ANALYZE THE PROBLEM*• List the unknowns. The knowns are listed in the table above. | **UNKNOWN***mass defect of deuterium* = ? *binding energy of deuterium* = ?*mass defect of helium* = ? *binding energy helium* = ?*SOLVE FOR THE UNKNOWN** Calculate the mass of the parts of deuterium.

mass of hydrogen: 1.007825 u mass of neutron: 1.008665 u mass of parts of deuterium: 2.016490 u* Calculate the mass defect of deuterium.

mass of deuterium: 2.014102 u mass of parts of deuterium: 2.016490 u mass defect of deuterium: 0.002388 u |
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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **The Strong Nuclear Force***Use with Example Problem 1.***Problem** Use the information in the table below to compare the mass defect and binding energy of deuterium, 21 , with that of helium, 2 e.

|  |
| --- |
| **KnownMasses** |
| *m*hydrogen atom | 1.007825 u |
| *m*neutron | 1.008665 u |
| *m*deuterium atom | 2.014102 u |
| *m*helium atom | 4.002603 u |

**Response***SKETCH AND ANALYZE THE PROBLEM*• List the unknowns. The knowns are listed in the table above. | **UNKNOWN***mass defect of deuterium* = −0.002388 u *binding energy of deuterium* = ? *mass defect of helium* = ? *binding energy helium* = ?*SOLVE FOR THE UNKNOWN** Calculate the mass of the parts of helium.

mass of 2 hydrogen atoms: 2.015650 u mass of 2 neutrons: 2.017330 u mass of parts of helium: 4.032980 u* Calculate the mass defect of helium.

mass of helium: 4.002603 u mass of parts of helium: 4.032980 u mass defect of helium: 0.030377 u |
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|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **UNKNOWN** **The Strong Nuclear Force** *mass defect of deuterium* = −0.002388 u*binding energy of deuterium* = ? *mass defect of helium* = −0.030377 u *Use with Example Problem 1.* **Problem** *binding energy helium* = ?Use the information in the table below to compare the mass defect *SOLVE FOR THE UNKNOWN* and binding energy of deuterium, • Calculate the binding energy for deuterium and

|  |
| --- |
| **KnownMasses** |
| *m*hydrogen atom | 1.007825 u |
| *m*neutron | 1.008665 u |
| *m*deuterium atom | 2.014102 u |
| *m*helium atom | 4.002603 u |

21 , with that of helium, 2 e. for helium. binding energy  mass defect 931.49 MeV/u   deuterium   0.002388 u 931.49 MeV/ubinding energy 2.2244 MeV helium    0.030377 u 931.49 MeV/ubinding energy 28.296 MeV **Response** *EVALUATE THE ANSWER* *SKETCH AND ANALYZE THE PROBLEM* • The binding energy and mass defect of helium • List the unknowns. The knowns are are about 10 time those of deuterium. listed in the table above. *Copyright © McGraw-Hill Education* The Nucleus |

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**The Strong Nuclear Force**

•

A more negative average binding energy indicates tightly bound nucleons and

a more stable nucleus.

•

The binding energy per nucleon depends on the mass of the nucleus.

The

most stable nucleus is iron

-

56.

•

Large, unstable nuclei will readily decay into smaller, more stable nuclei. For

example, all nuclei with atomic

numbers

greater than 92

decay

readily.

•

Under certain conditions,

such

as

high

temperature,

nuclei

smaller than iron

-

56

can

fuse into larger, more

stable

nuclei.



The binding energy per nucleon changes as the number of nucleons (A) varies. Iron-56 has the most tightly bound nucleus and is the most stable isotope known.

 𝟏𝟑𝟏 𝟐𝟑𝟔

***Q: Infer which nucleus*** 𝑰 ***or Pu, would you expect to have a larger-magnitude average binding*** 𝟓𝟐 𝟗𝟒

***energy per nucleon?***

**Activity: Complete the following problems.**

Use these values to solve the following problems:

*Mass of hydrogen = 1.007825 u*

*Mass of neutron = 1.008665 u*

*1 u = 931.49MeV*

1. The carbon isotope 12C has a mass of 12.000000 u. 6
	1. Calculate its mass defect.
	2. Calculate its binding energy.

1. Deuterium (2H) has a mass of 2.014102 u. 1
	1. Calculate its mass defect.
	2. Calculate its binding energy.

1. The nitrogen isotope (2H) has a mass defect of -0.113986 u.

1

* 1. Calculate the mass of this isotope.
	2. Calculate the binding energy of the nucleus.