英华国际学校
YINGHUA INTERNATIONAL SCHOOL

Cambridge IGCSE Physics
Nuclear Physics

By: Chaoyang Chu

Learning objectives

5.1 The nuclear model of the atom	5.1.1 Atomic structure 5.1.2 Protons, neutrons, and electrons
5.2 Radioactivity	5.2.1 Radioactivity all around 5.2.2 The microscopic picture 5.2.3 Radioactive decay 5.2.4 Using radioisotopes

Section 5.1

The nuclear atom

5.1.1 Atomic structure

5.1.2 Protons, neutrons, and electrons

Section 5.1

The nuclear atom

5.1.1 Atomic structure

5.1.2 Protons, neutrons, and electrons

Atom

10 drachma

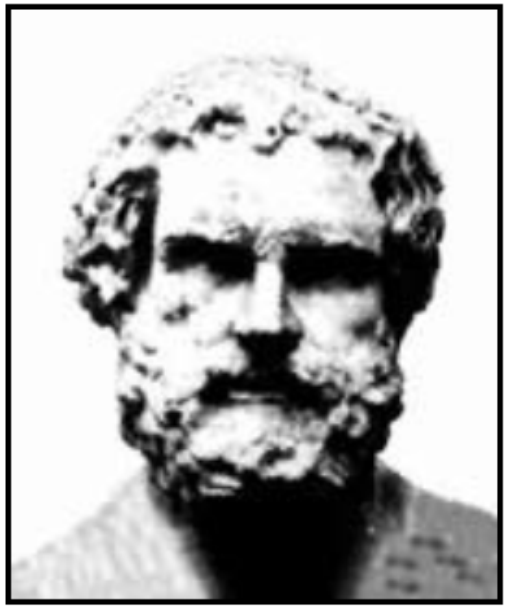
Atom

- These coins have a portrait of Democritus (古希腊哲学家得谟克里特) with his name inscribed in Greek. Democritus (460 - 370 BC) was a Greek philosopher, who developed the atomic theory of the universe. According to his exposition of the atomic theory of matter, all things are made up of vast numbers of tiny particles.

- The reverse side of the coin shows a modern image of a single atom (原子). Democritus would not have imaged that an atom could be subdivided into a nucleus and electrons.

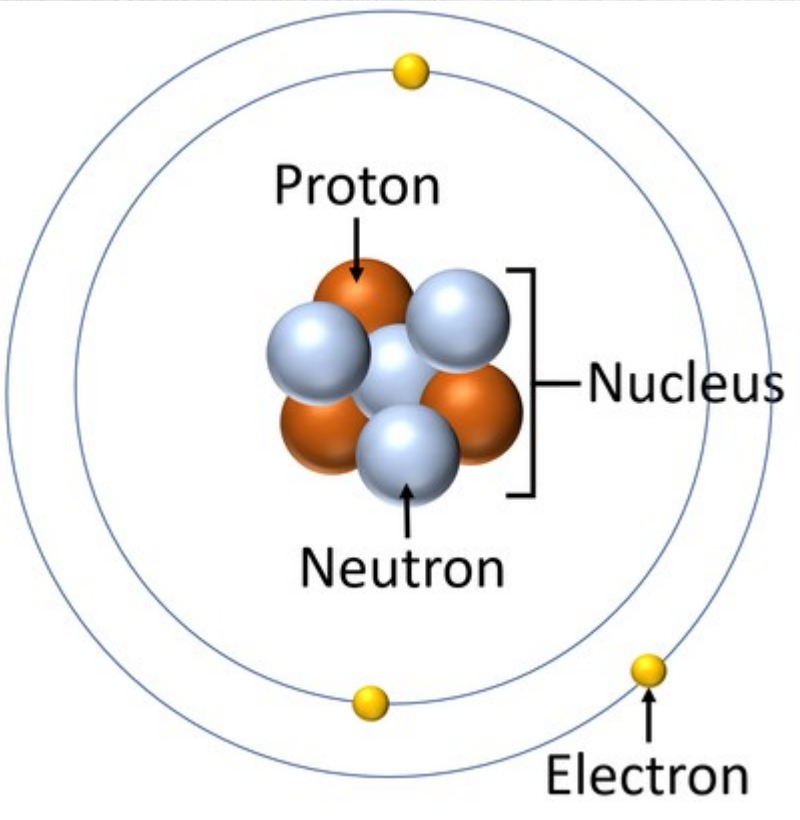
Atom

Ancient Atomic Theory



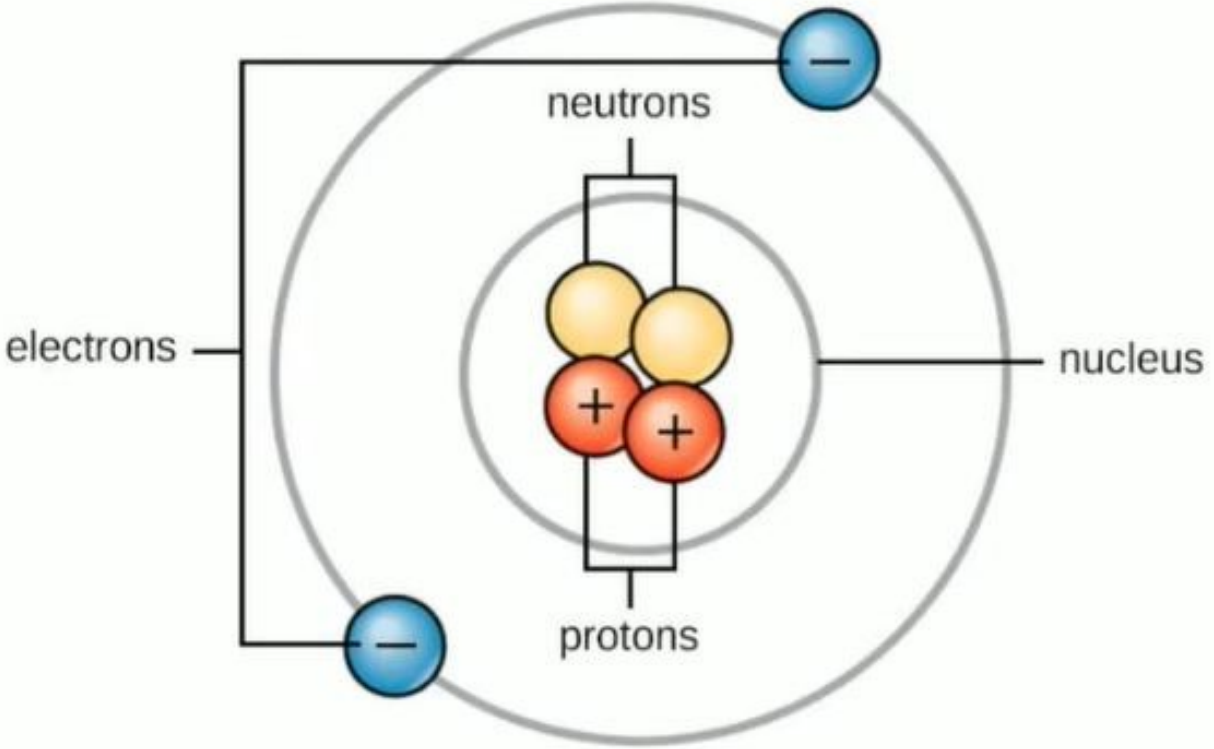
One of the first atomic theorists was Democritus, a Greek philosopher who lived in the fifth century BC. Democritus knew that if a stone was divided in half, the two halves would have essentially the same properties as the whole.Therefore, he reasoned that if the stone were to be continually cut into smaller and smaller pieces then; at some point, there would be a piece which would be so small as to be indivisible. He called these small pieces of matter "*atomos*," the Greek word for indivisible. Democritus, theorized that atoms were specific to the material which they composed. In addition, Democritus believed that the atoms differed in size and shape, were in constant motion in a void, collided with each other; and during these collisions, could rebound or stick together. Therefore, changes in matter were a result of dissociations or combinations of the atoms as they moved throughout the void. Although Democritus' theory was remarkable, it was rejected by Aristotle, one of the most influential philosophers of Ancient Greece; and the atomic theory was ignored for nearly 2,000 years.

Atomic structure



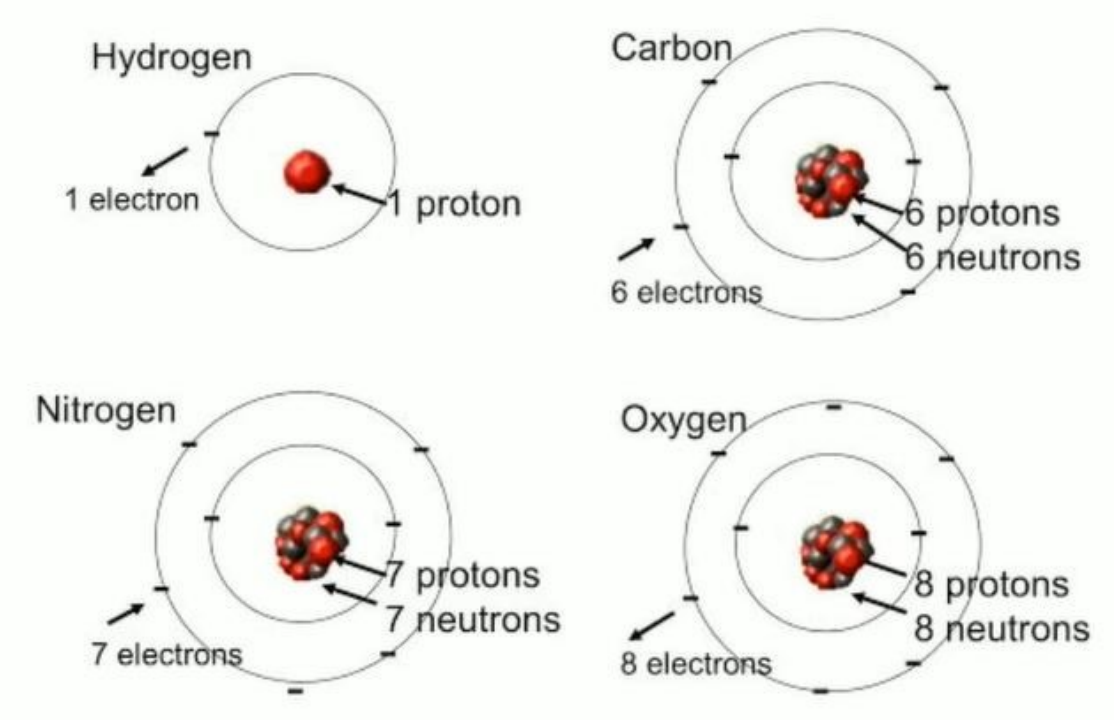
- An atom is the smallest unit of ordinary matter that forms a chemical element.
- Every solid, liquid, gas, and plasma is composed of neutral or ionized atoms.
- Atoms are extremely small, typically around 100 picometers (10^-12) across.

Atomic structure



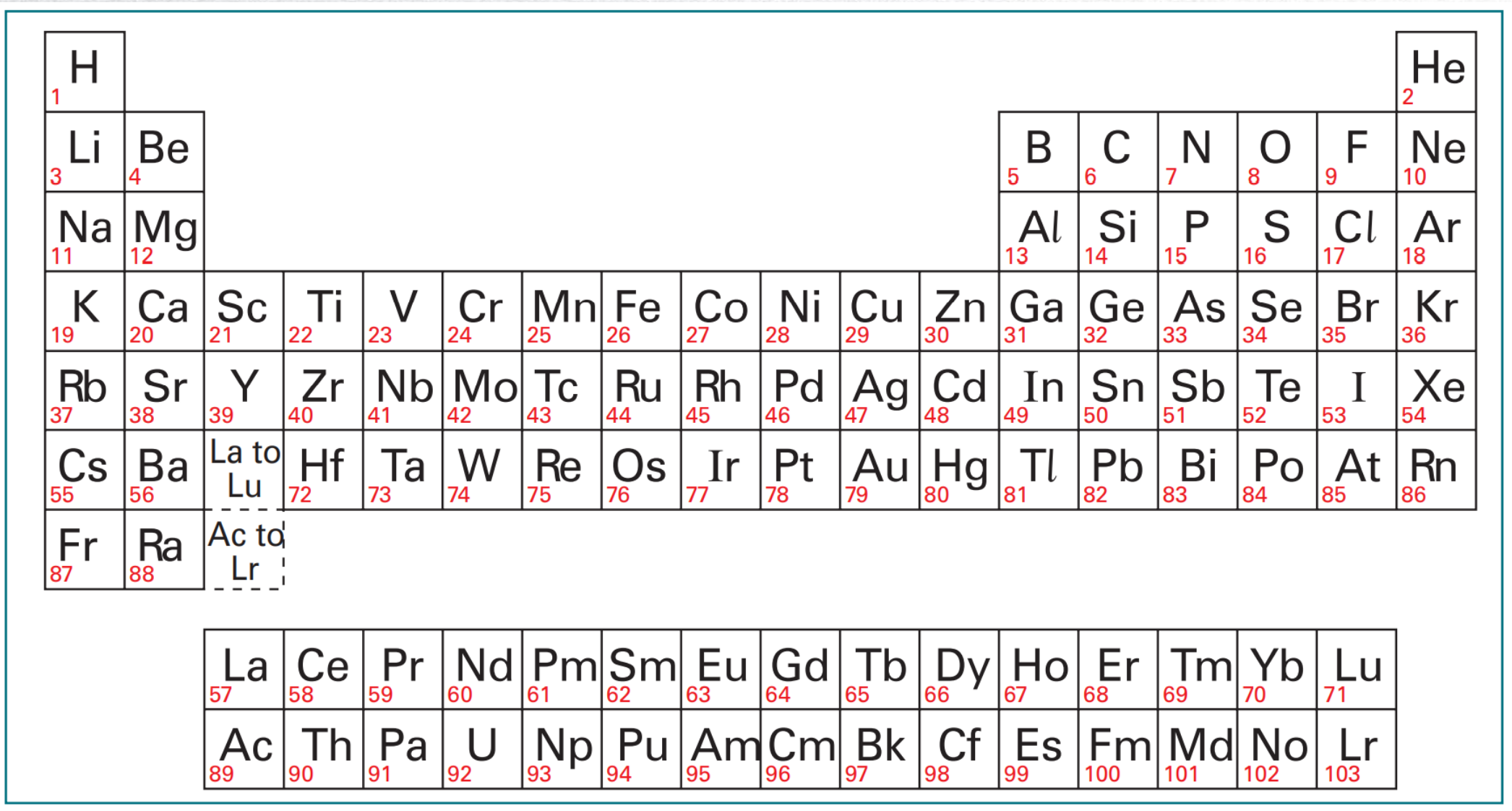
SUBATOMIC PARTICLES			
Name	Symbol	Charge	Relative mass
Electron	e^-	-1	1/1840
Proton	p^+	+1	1
Neutron	n^0	0	1

What makes an atom unique?



- There are currently 109 different atoms
- A substance made entirely of just one type of atom is called an **element**
- Every atom has **a different number of protons in the nucleus**
- This also means that each atom has a different number of electrons
- Different atoms behave differently because of the difference in proton/electron numbers

What makes an atom unique?



Rutherford alpha scattering experiment

Observation	Interpretation
Most α particles travel through the foil undeflected	The atom is mostly empty space
Some α particles are deflected by small angles	The nucleus is positively charged, as is the α particle
Occasionally, an α particle travels back from the foil	The nucleus carries most of the atom's mass

- The scattering of alpha (α) particles by a sheet of thin metal supports the nuclear model of the atom, by providing evidence for:

  (a) a very small nucleus surrounded by mostly empty space

  (b) a nucleus containing most of the mass of the atom

  (c) a nucleus that is positively charged

THANK YOU

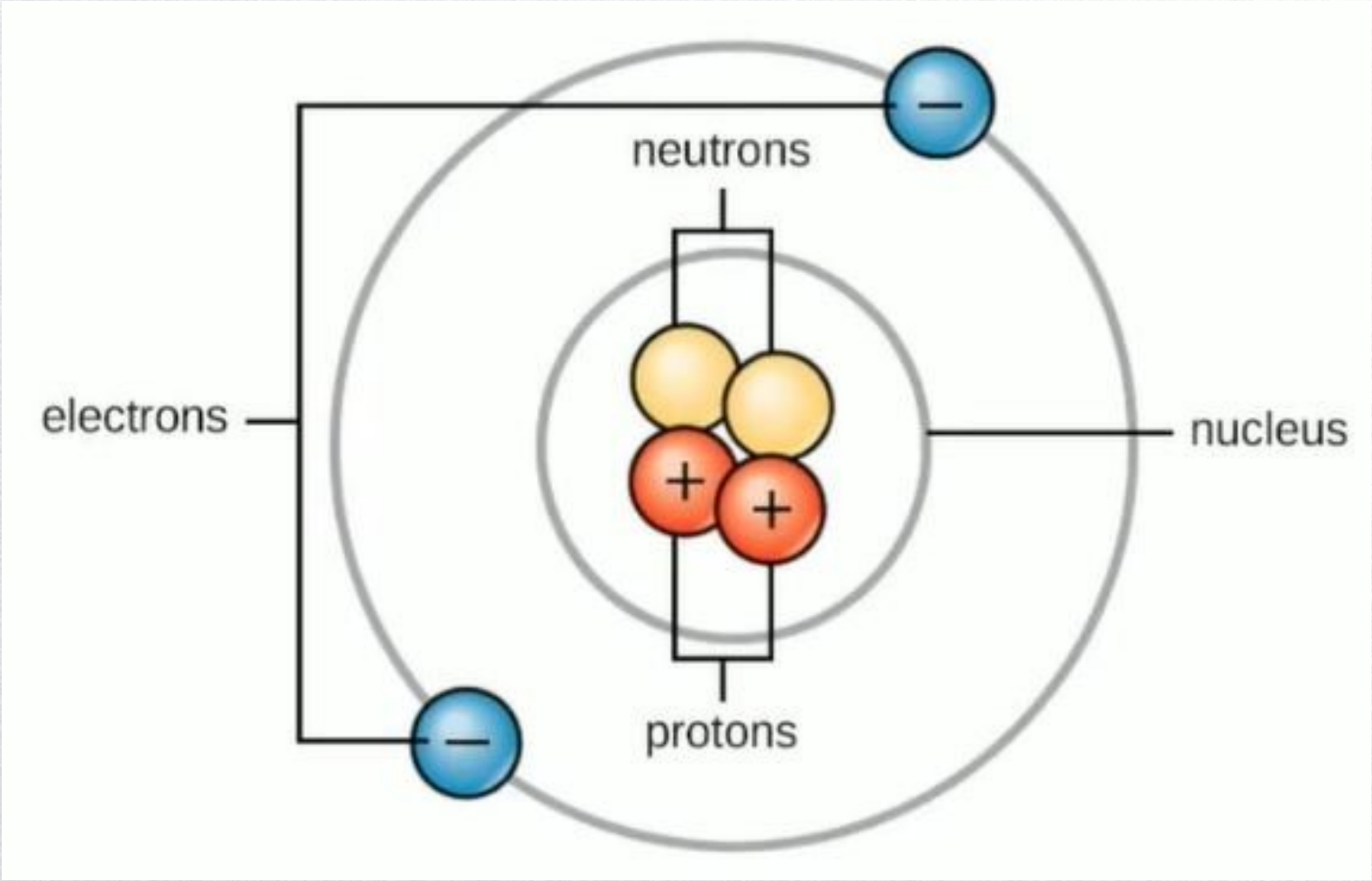
Section 5.1

The nuclear atom

5.1.1 Atomic structure

5.1.2 Protons, neutrons, and electrons

The 3 sub-atomic particles



The 3 sub-atomic particles

Particle	Position	Charge / C	Relative charge	Mass / kg	Relative mass
proton	in nucleus	$+1.6\times10^{-19}$	+1	1.67×10^{-27}	1
neutron	in nucleus	0	0	1.67×10^{-27}	1
electron	orbiting nucleus	-1.6×10^{-19}	−1	9.11×10^{-31}	$\frac{1}{1836}$ (approx. 0)

Charges and masses of the 3 sub-atomic particles

The 3 sub-atomic particles

- The **nucleus** of an atom contains **protons** and **neutrons**. It makes up most of the mass of the atom, but takes up virtually no space.
- Protons and neutrons make up most of the weight of the entire atom
  - ✓ **proton**s have a **positive (+) charge**
  - ✓ **neutron**s have **no charge**

- **Electron**s are much smaller (virtually weightless) particles that orbit around the nucleus
  - ✓ **electron**s have a **negative (-) charge**

- A neutral atom means that it has **no net charge**: the number of protons (+) = number of electrons (-)
- By losing or gaining electrons, atoms can become charged – **charged atoms** are called **ions**
  - ✓ atoms may form **positive (+) ions** by **losing** electrons
  - ✓ atoms may form **negative (-) ions** by **gaining** electrons

Atoms and elements

nucleus 原子核	The positively charged central core of an atom, consisting of protons and neutrons and containing nearly all its mass.
nucleon 核子	A particle found in the atomic nucleus: a proton or a neutron
nuclide 核素	A ‘species’ of nucleus having particular values of proton number and nucleon number

Atoms and elements

Nucleus (原子核):

- *protons*
- *neutrons*

Atomic number (Z) = Proton number (Z)

Mass number (A) = *Nucleon（核子）number (A)*

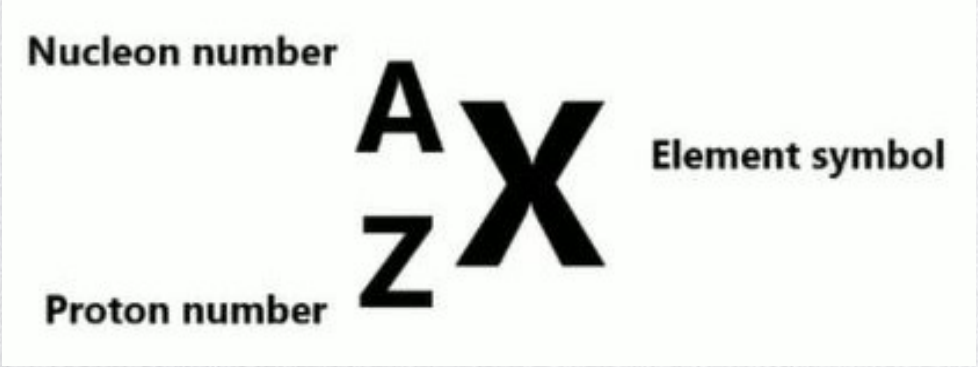
$$= \sum number\ of\ (proton + neutrons)$$

Number of protons = number of electrons

Nuclide

- For any given atom:
  - ✓ **Proton number (Z)** is the number of protons in the nucleus
  - ✓ **Nucleon number (A)** is the sum of protons and neutrons

- The nuclide of an atom represents these values in the form of :



Nuclide

- A neutral atom of element X will also have Z electrons orbiting the nucleus. There are just over a hundred different elements X, all of which have **different possible combinations of Z and A, each giving a different type of nucleus**. Each type is called a **nuclide**.
- Sometimes physicists refer to nuclides as **nuclear species**, as if all the different species make up a ‘zoo’ of nuclei (原子核).

Nuclide

The nucleus of an atom of element X is written as

$${}^{A}_{Z}\mathrm{X}$$

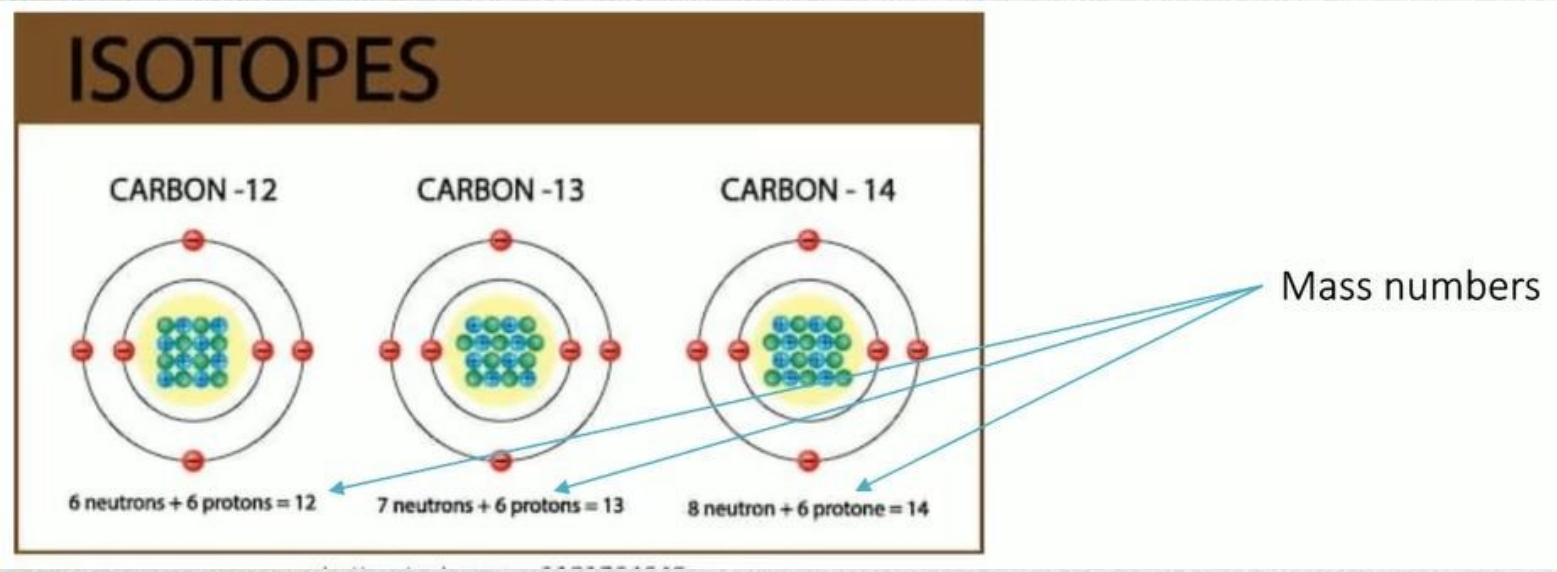
where Z is the proton number and A is the nucleon number.

$$\text{proton number} + \text{neutron number} = \text{nucleon number}$$

$$Z + N = A$$

Elements & Isotopes

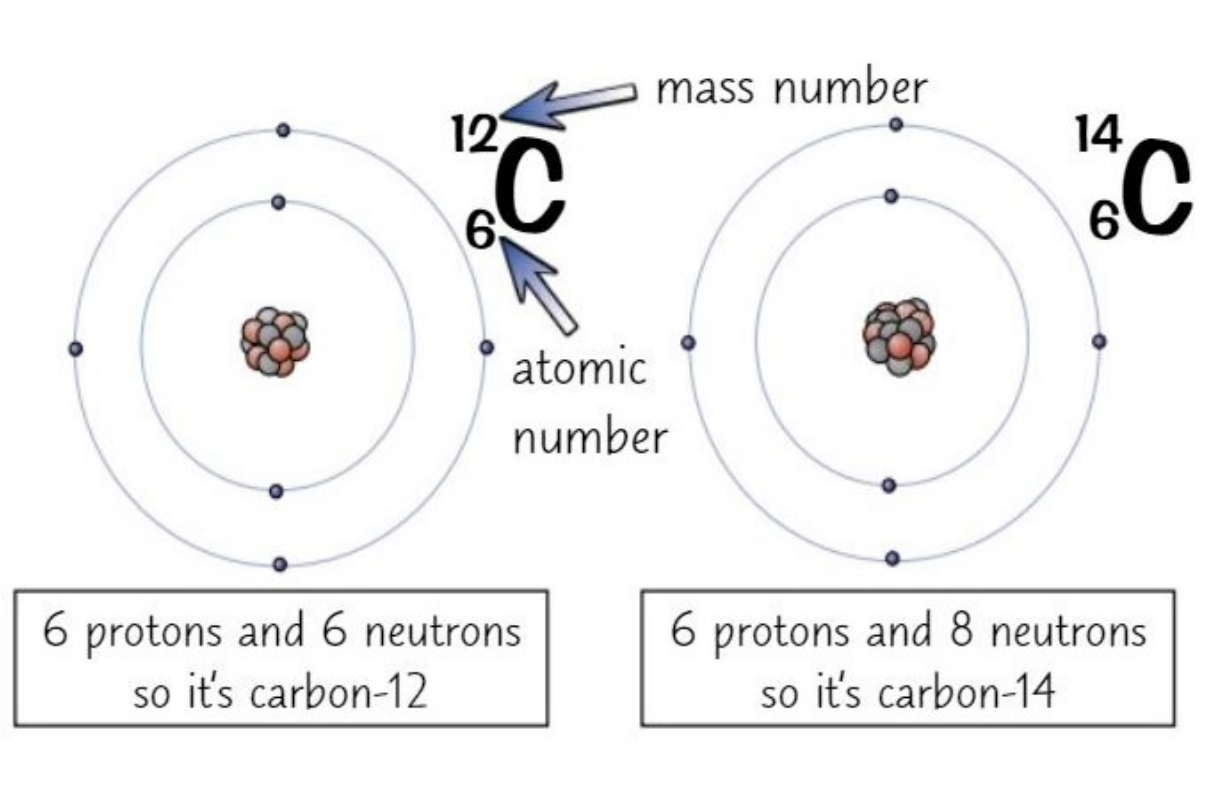
- Isotopes are atoms with the same number of protons (i.e. the same atomic number) but a different numbers of neutrons.
- Many elements have a few different isotopes.
- Usually, each element only has one or two **stable** isotopes – like carbon-12. The other isotopes tend to be **radioactive** – the nucleus is **unstable**, so it **decay**s and emits **radiation**. Carbon-14 is an unstable isotope of carbon.



Elements & Isotopes

Symbol for isotope	Proton number *Z*	Neutron number *N*	Nucleon number *A*
${}_{1}^{1}\mathrm{H}$	1	0	1
${}_{1}^{2}\mathrm{H}$	1	1	2
${}_{1}^{3}\mathrm{H}$	1	2	3
Symbol for isotope	**Proton number *Z***	**Neutron number *N***	**Nucleon number *A***
${}_{92}^{235}\mathrm{U}$	92	143	235
${}_{92}^{238}\mathrm{U}$	92	146	238

Elements & Isotopes



Isotopes:

- are variants of the same atom
- have the **same proton/electron number**
- have a **different neutron number**
- therefore, they have **different mass number**
- the different isotopes of an element all have the **same chemical properties**

Isotopes

Study question:

Which of the following represents an isotope of $^{14}_{7}\mathrm{N}$: $^{15}_{7}\mathrm{N}$ or $^{14}_{8}\mathrm{N}$? Explain your answer.

Isotopes

Study question:

Which of the following represents an isotope of $^{14}_{7}\mathrm{N}$: $^{15}_{7}\mathrm{N}$ or $^{14}_{8}\mathrm{N}$? Explain your answer.

$^{15}_{7}\mathrm{N}$ is an isotope of $^{14}_{7}\mathrm{N}$. Isotopes are atoms with the same atomic number but different mass numbers.

THANK YOU