ATOMIC STRUCTURE AND THE PERIODIC TABLE

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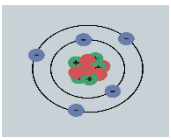
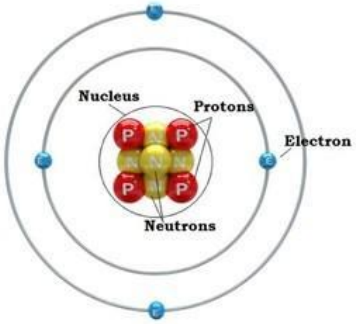
ATOMIC STRUCTURE



- Elements are made of tiny particles of matter called **atoms**
- Each atom is made of subatomic particles called **protons**, **neutrons** and **electrons**
- Their size is so tiny that we can't really compare their masses in conventional units such as kilograms or grams, so a unit called the **relative atomic mass** is used
- One **relative atomic mass** unit is equal to $1/12^{th}$ the mass of a carbon-12 atom.
- All other elements are measured relative to the mass of a carbon-12 atom, so relative atomic mass has no units (although sometimes you may come across a unit Da or u which stands for a Dalton and it means the same thing)
- Hydrogen for example has a relative atomic mass of 1, meaning that 12 atoms of hydrogen would have the same mass as 1 atom of carbon
- The relative mass and charge of the subatomic particles are shown below:

PARTICLE	RELATIVE MASS	CHARGE
PROTON	1	+1
NEUTRON	1	0 (NEUTRAL)
ELECTRON	$\frac{1}{1840}$	−1

Every atom has a basic **nucleus** at the center, consisting of a certain number of protons and neutrons. The number of these particles is different for different elements. Around the nucleus, there is a certain number of **electrons** in fixed orbits, at fixed energy levels.



The electron is by far the smallest: At 9.11 x 10^{-31} kg. It carries a negative electrical charge. Usually, it is bound to the positively charged nucleus due to the attraction created from the opposite electric charges. If the electrons carried by an atom are more or fewer than its atomic number, then the atom becomes respectively negatively or positively charged. A charged atom is known as an ion.

Most of the **mass** of the atom comes from the protons and neutrons themselves, whereas electrons are almost 1/1837th times the weight of a proton or neutron. Protons and neutrons are both composed of other particles called quarks and gluons.

The **atomic number** is the number of protons (equal to the number of electrons in a neutral atom) in the atom and the **atomic mass number** is the sum of the number of protons and neutrons in the atom. The **atomic number** (Z) is defined as the number of units of positive charges (protons) in the nucleus. It is the number of protons in the nucleus that determines the chemical properties of an atom. **Nucleon number** (or **mass number**) is the total number of protons **and** neutrons in the nucleus of an atom. The symbol for nucleon number is ***A.*** The nucleon number **minus** the proton number gives you the number of **neutrons** of an atom. Note that protons and neutrons can collectively be called **nucleons**. **Electrons** - The symbol for an electron is e^-, but other symbols are used such as **x** and • in bonding diagrams to make it easier to see where electrons come from. These subatomic particles move very fast around the nucleus. They move in orbital paths called **shells**. The mass of the electron is negligible, hence the mass of an atom is concentrated in the nucleus where the neutrons and protons are found.

An atom may gain a positive or negative charge by either losing or gaining electrons respectively. Atoms may attach themselves to each other (of the same type or different type) to form molecules of different compounds, to form matter.

Isotopes

- Isotopes are atoms of the **same element** that contain the same number of **protons** and elec**t**rons but a different number of **neutrons**
- The symbol for an isotope is the chemical symbol (or word) followed by a dash and then the mass number
- So C-14 is the isotope of carbon which contains 6 protons, 6 electrons and 14 - 6 = 8 neutrons.

Types of Isotope

Isotopes can be divided into two categories: radioactive and non-radioactive

Radioactive isotopes (radioisotopes) are unstable due to the imbalance of neutrons and protons, which causes the nucleus to decay over time through nuclear fission and emit radiation

Examples of radioisotopes include tritium and carbon-14

Decay occurs at a different rate for each isotope, but the time taken for the radioactivity of an isotope to decrease by 50% is constant for that particular isotope and is known as the half-life

Radioactive isotopes have numerous medical and industrial uses

Non-radioactive isotopes are stable atoms that only differ in their mass

Electron shells

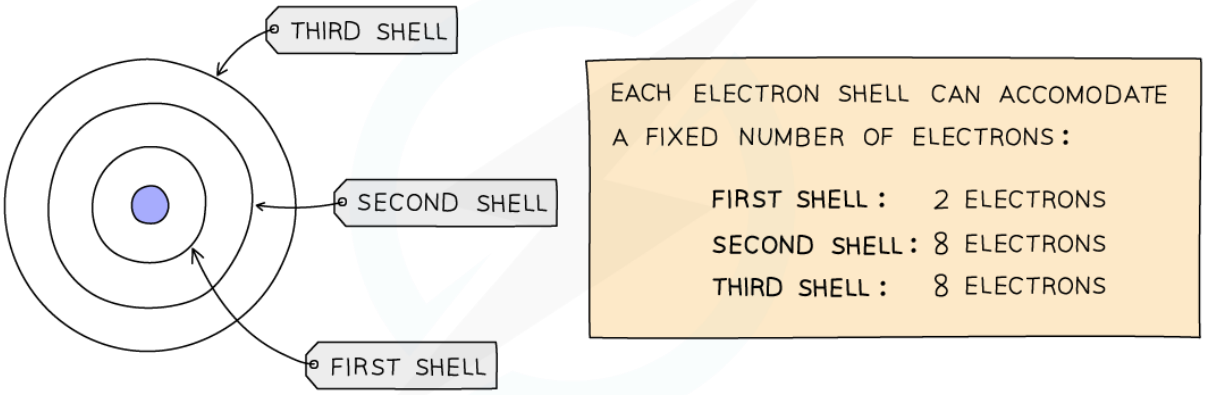
Electronic structure

- We can represent the structure of the atom in two ways: using diagrams called **electron shell diagrams** or by writing out a special notation called the **electronic structure**

Electron shell diagrams

- Electrons orbit the nucleus in **shells** (or **energy levels**) and each shell has a different amount of energy associated with it
- The further away from the nucleus then the more energy a shell has

- Electrons occupy the shell closest to the nucleus which can hold only **2** electrons
- When a shell becomes full, electrons then fill the next shell
- The second shell can hold **8** electrons and the third shell can also hold **8** electrons. The electrons organise themselves in pairs in these shells
- The outermost shell of an atom is called the **valence** shell and an atom is much more stable if it can manage to completely fill this shell with electrons



Bonding: the Structure of Matter

Types of Substance & Properties

Elements, compounds and mixtures

- All substances can be classified into one of these three types

Element

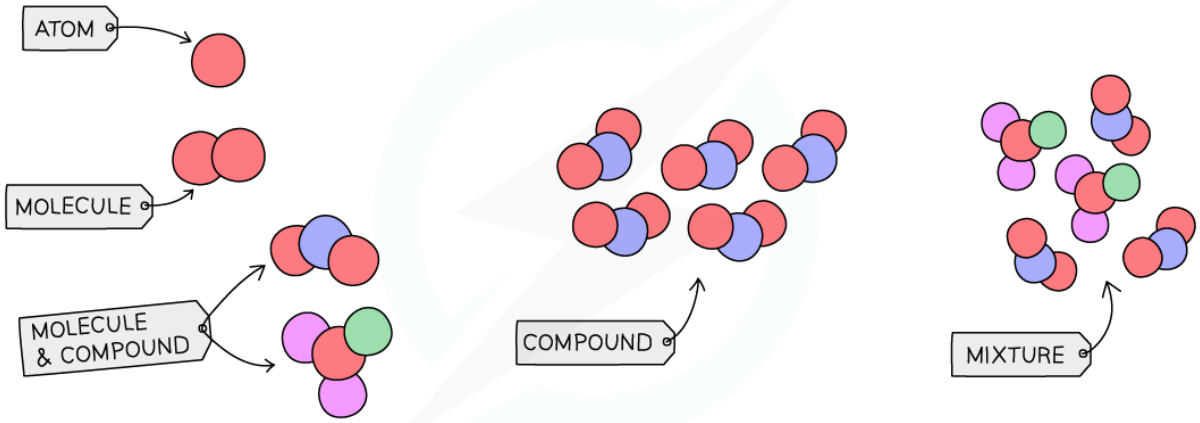
- A substance made of atoms that all contain the **same number of protons** and cannot be split into anything simpler
- There are 118 elements found in the Periodic Table

Compound

- A pure substance made up of two or more elements **chemically combined**
- There is an **unlimited** number of compounds
- Compounds cannot be separated into their elements by physical means
- Eg copper(II) sulphate ($CuSO_4$), calcium carbonate ($CaCO_3$), carbon dioxide (CO_2)

Mixture

- A combination of two or more substances (elements and/or compounds) that are **not** chemically combined
- Mixtures can be separated by **physical methods** such as filtration or evaporation
- Eg sand and water, oil and water, sulphur powder and iron filings



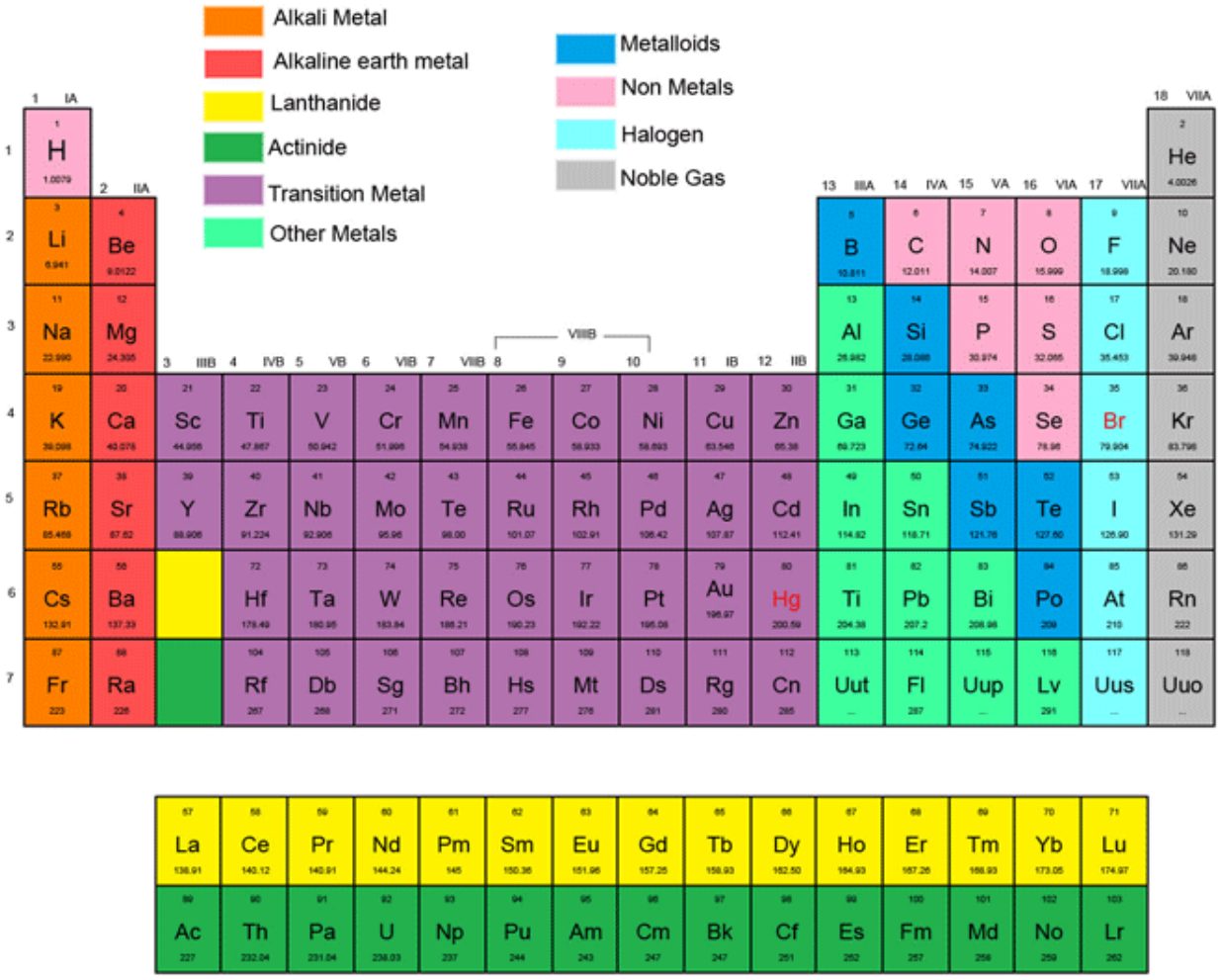
The Periodic Table

The **periodic table** is a table that logically organizes all the known elements. Each **element** has a specific location according to its atomic structure. Each row and column has specific characteristics.

The Basis of the Periodic Table

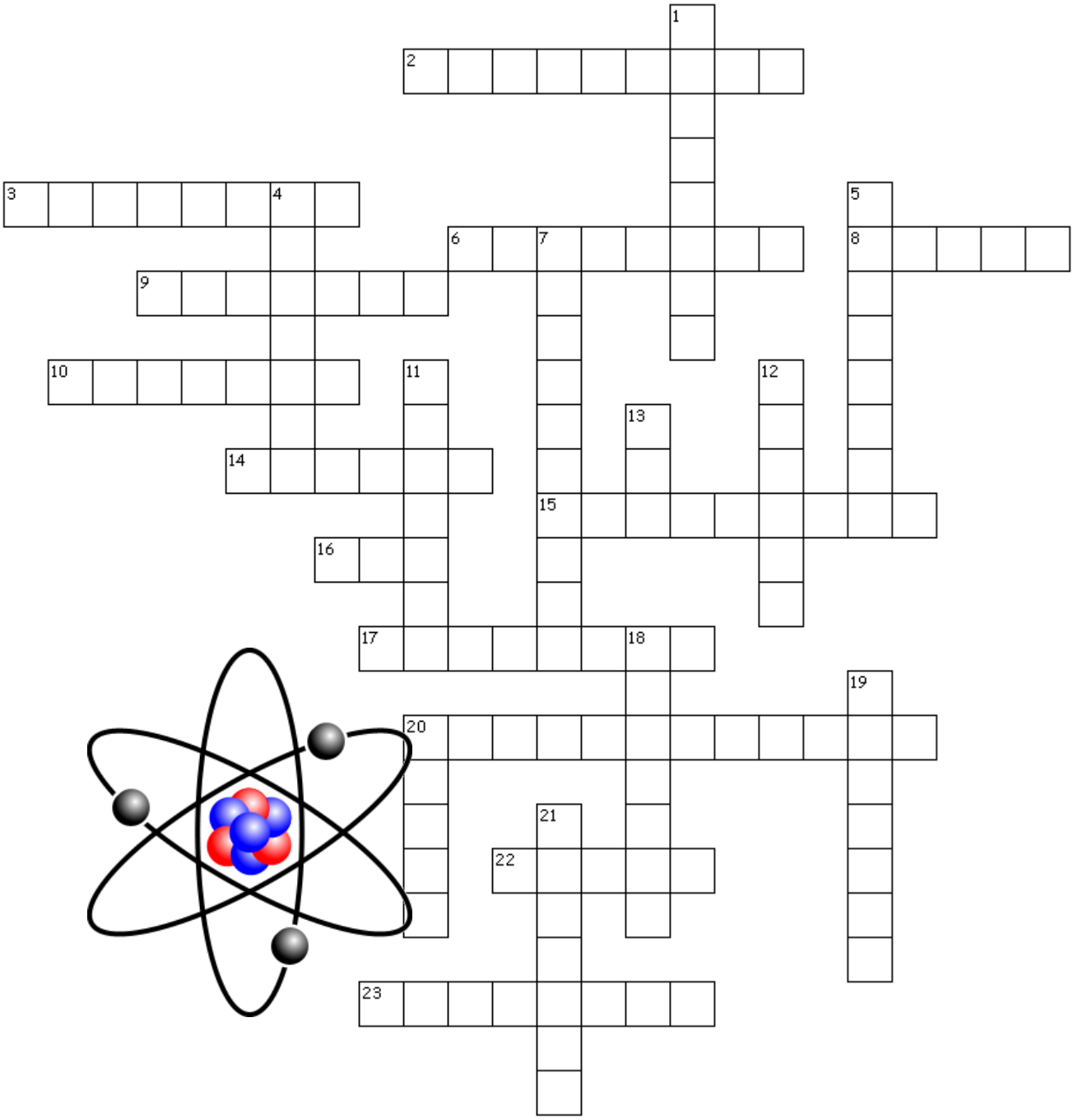
- Elements are arranged on the Periodic Table in order of **increasing atomic number** where each element has one proton **more** than the element preceding it
- Hydrogen has 1 proton, helium has 2 protons, lithium has 3, etc.
- The table is arranged in vertical columns called **Groups** numbered I - VIII and in rows called **Periods.**
- Each row is called a period where all of the elements have the same number of atomic orbitals. For example, every element in the top row (the first period) has one orbital for its electrons. All of the elements in the second row (the second period) have two orbitals for their electrons. As you move down the table, every row adds an orbital. At this time, there is a maximum of seven electron orbitals.

- Each column is called a **group** where the elements have the same number of electrons in the outer **orbital**. Those outer electrons are also called **valence electrons**. They are the electrons involved in chemical bonds with other elements. Every element in the first column (group one) has one electron in its outer shell. Every element in the second column (group two) has two electrons in the outer shell
- Elements in the same group have the same amount of electrons in their **outer shell**, which gives them **similar chemical properties**
- **Mendeleev** discovered the periodic table (or Periodic System, as he called it) while attempting to organize the elements in February of 1869.
- The periodic table can be used also to estimate relatively some other properties of the atoms: electronegativity, ionization energy, electron affinity, atomic radius, melting point, and metallic character.



Activity 1:

Complete the crossword puzzles using the hints given.



Across

2. Very small negatively charged particles orbiting the nucleus

3. If an atom loses electrons it becomes a _____ ion

6. Two or more elements chemically combined

8. The maximum number of electrons the second energy level/shell can hold

9. This number is also called the mass number

10. Consists of one kind of atom only

14. A horizontal column in the periodic table

15. The Russian Scientist who created the Periodic Table

16. The maximum number of electrons the first energy level/shell can hold

17. Uncharged particles in the nucleus of an atom

20. Number of protons in the nucleus of an atom (two words)

22. A vertical column on the periodic table

23. The table of the elements

Down

1. Substance made up of two or more identical atoms

4. Another name for the outer shell of electrons

5. If an atom gains electrons it becomes a _____ ion

7. The number of protons & neutrons in the nucleus (two words)

11. Atoms with the same atomic number but a different mass number

12. Electrons travel around the nucleus in energy levels or _____

13. An atom that has lost or gained electrons

18. Central part of an atom containing protons & neutrons

19. The charge on an atom with equal numbers of protons & electrons

20. Made up of protons, neutrons and electrons

21. Particles with a positive charge in the nucleus

Choose from: Neutral ; Ion; Neutrons; Two; Negative; Nucleus; Massnumber; Nucleon; Atoms; Atomic number; Positive; Periodic; Molecule; Electrons; Protons; Eight; Compound; Shells; Group; Period; Isotope; Valence; Mendeleev ; Element

Activity 2:

Complete the grid by drawing diagrams to show the electronic structure of atoms with the following numbers of electrons.

1 electron	2 electrons	3 electrons
4 electrons	5 electrons	6 electrons
7 electrons	8 electrons	9 electrons
10 electrons	11 electrons	16 electrons

18 electrons	19 electrons	20 electrons

Activity 3:

Neutrons

- The *atomic number* of an element is the number of protons in an atom.

- The *mass number* of an atom is the total number of protons and neutrons in an atom.

- So the number of neutrons = mass number – atomic number.

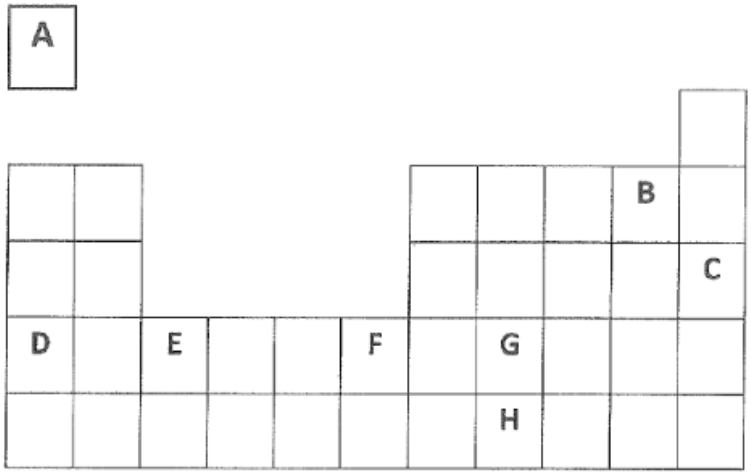
Complete the table to show how many neutrons each atom contains.

Atom	**Symbol**	**Mass number**	**Atomic number**	**Neutrons**
Hydrogen		1		
Helium		4		
Lithium		7		
Beryllium		9		
Boron		11		
Carbon		12		

Nitrogen		14		
Oxygen		16		
Fluorine		19		
Neon		20		
Sodium		23		
Magnesium		24		
Aluminium		27		
Silicon		28		
Phosphorus		31		
Sulphur		32		
Chlorine		35		
Argon		40		
Potassium		39		
Calcium		40		

Activity 4:

Use the shortened blank periodic table below to answer the questions



1. Which is the smallest/lightest element labelled above?

2. Name the three elements shown above that are nonmetals.

3. Which element is in the alkali metal family?

4. Which element is in the halogen family?

5. What number period are elements D, E, F, and G in?

6. What is the largest/heaviest element labelled above?

7. Which two elements would fall within the transition metals group?

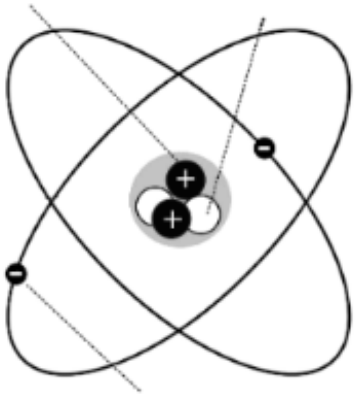
8. Which element is in the noble gases family?

9. If element F had an atomic number of 22, what would be the atomic number of G?

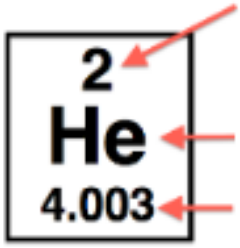
a. What would be the atomic number of element E?

Activity 5:

Label a proton, neutron, and electron in the atom of helium shown below.



Label the atomic number, atomic mass, and element symbol of helium



10. The atomic number tells you the number of _____ in the nucleus.

11. In a neutral atom, the number of _____ and _____ will be the same.

12. What is the unit that the atomic mass is measured in?

13. The atomic mass tells you the total number of _____ and _____ since they are the heaviest parts of the atom.

References

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