التفاعلات الكيميائية تعتمد على توزع إلكترونات التكافؤ في مدار التكافؤ .. الإلكترونات البعيدة

١- العناصر التي تحمل نفس العدد من الإلكترونات تتصف بالخصائص نفسها (مثل الهالوجينات الكلور Cl والفلور F واليود I، والمعادن الترابية البوتاسيوم K والصوديوم Na والكالسيوم Ca

Elements with the same number of electrons on the valence shell have the same characters (such as halogens : Cl and F …)

٢- في العناصر الخاملة اكتمل عدد الإلكترونات في مدار التكافؤ عندها

inert elements have complete valence shell

٢.٣ شكل الجزيئات ووظائفها تعتمد على الروابط الكيميائية بين الذرات

2.3-Formation & Function of Molecules Depend on chemical bonding

- تتأثر الذرات غير مكتملة مدار تكافئها مع الذرات الأخرى بحيث يكتمل مدار تكافؤ كل منها **by completing valence shell**
- تتم التفاعلات باكتمال مدار التكافؤ، وذلك باشتراك إلكترونات التكافؤ **sharing valence electrons** أو انتقالها **transferring them** من ذرة إلى أخرى.
- يتم الارتباط بروابط كيميائية chemical bonds
- هناك:

1 - روابط تشاركية (مشتركة- تساهمية) **Covalent bonds**

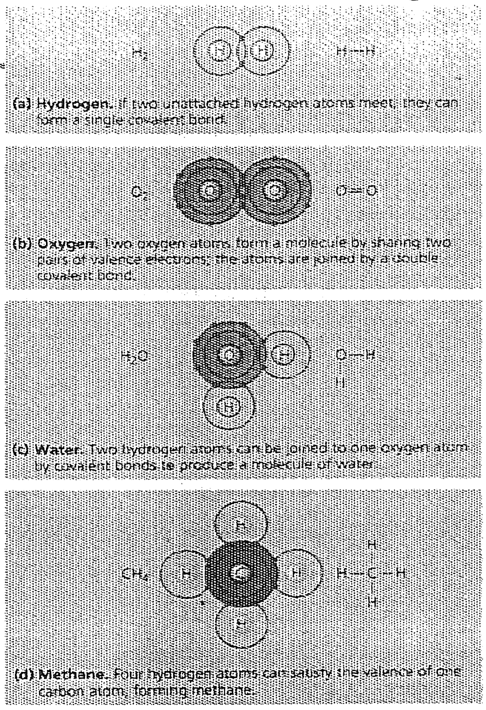
٢ - روابط إيونية **Ionic bonds** كلاهما روابط قوية

٣- روابط هدروجينية **Hydrogen bonds**

٤- روابط أخرى مثل روابط (تآثرات) فاندرفالس **Other bonds such as Van der Waals interactions** كلاهما روابط ضعيفة

Strong bonds الروابط القوية

١ـ الروابط التشاركية: باشتراك sharing إلكترونات التكافؤ بين ذرتين



(a) **Hydrogen.** If two unattached hydrogen atoms meet, they can form a single covalent bond.

(b) **Oxygen.** Two oxygen atoms form a molecule by sharing two pairs of valence electrons; the atoms are joined by a double covalent bond.

(c) **Water.** Two hydrogen atoms can be joined to one oxygen atom by covalent bonds to produce a molecule of water.

(d) **Methane.** Four hydrogen atoms can satisfy the valence of one carbon atom, forming methane.

يميز نوعين من هذه الروابط two kinds of covalent bonds:

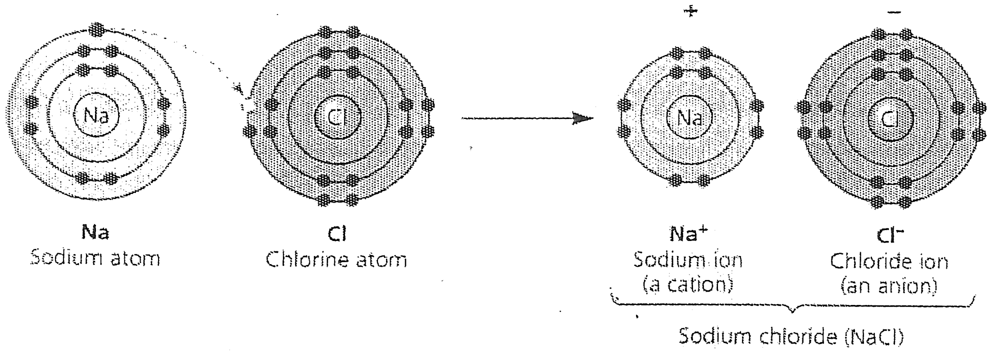
أ) روابط فردية single covalent bonds H^2 و NH^3

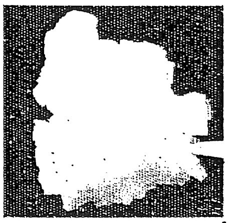
ب) روابط مضاعفة double bonds O^2 و H^2O و CH^4

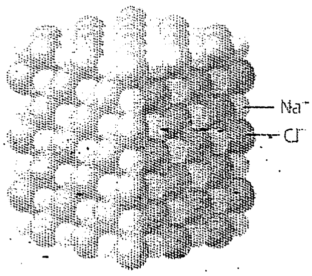
لذا عدد الإلكترونات المتشاركة يحدد عدد الروابط

٢- الرابطة الإيونية **Ionic bond**

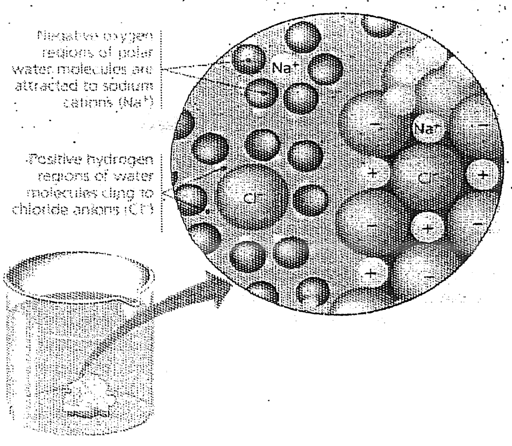
- رابطة بين ذرتين تنزع stripe إحداهما إلكتروناً من الذرة الأخرى .. أي ينتقل إلكترون من ذرة إلى ذرة أخرى **transfer of an electron from one atom to another one**
- مثل الصوديوم والكلور من ملح كلور الصوديوم ... شارجبة cation و شارسبة anion







- ما علاقة هذه الإيونات من الماء ؟ .... طبقة تميه **hydration shell**

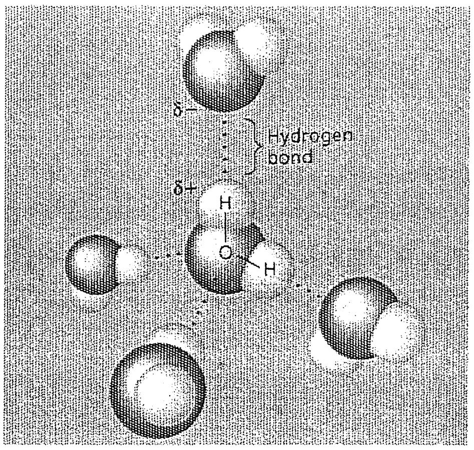


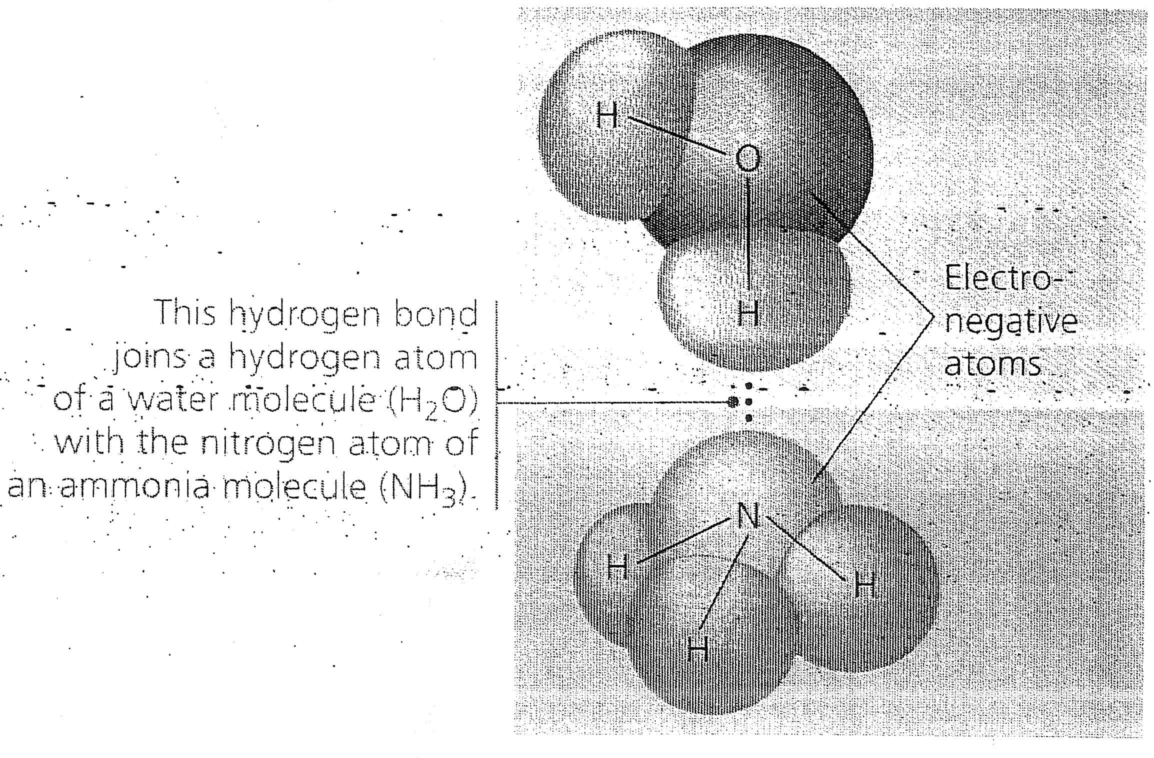
الروابط الكيميائية الضعيفة Weak Chemical Bonds

- الروابط التشاركية (التساهمية) covalent bonds أقوى الروابط ، لكن الروابط الضعيفة لابد منها، أما الروابط في الكائنات الحية دائماً ضعيفة
- ما هي أهمية أهمية الروابط الضعيفة في المنظومات الحية ؟ الإشارات الدماغية signaling brain
- إحدى هذه الروابط المهمة هي الروابط الإيونية .... لكن الأهم

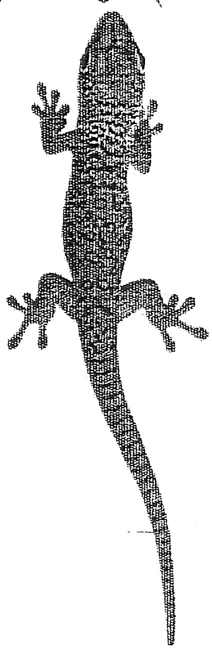
٣) الرابطة الهيدروجينية Hydrogen Bond

- تتشكل الرابطة الهيدروجينية بارتباط الهيدروجين (موجب الشحنة) تشاركياً من ذرة مع ذرات (سالبة الشحنة) من ذرة أخرى
-
-





٤) تأثرات فاندر فالس van der Waals interaction



• يتحرك الحيوان من خلالها (التي تحدث في الشعيرات الدقيقة في نهايات أصابع الحيوان) ملتصقاً على الجدران رغم إحاطة جسمه بحراشف عظمية، إنه من الزواحف

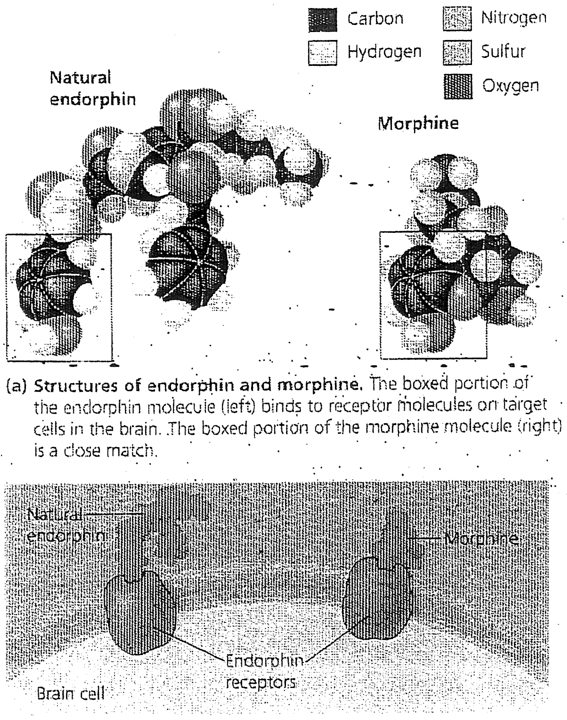
Gecko lizard أبو بريص can walk on walls because of this interaction that takes place between the hundreds of tiny hairs on its toes and the wall.

– تتحرك الإلكترونات دوماً حول النواة، أحياناً تتجمع الإلكترونات في منطقة ما فتصبح هذه المنطقة سالبة الشحنة، ينشأ مقابلها منطقة موجبة الشحنة.... **إذا حدث ذلك لأعداد كبيرة من الذرات** صارت هذه المنطقة بقعة ساخنة **hot spots** فتتمكن هذه المنطقة بالالتصاق بالمناطق الأخرى مثل الجدران، برابطة تسمى رابطة فاندرفالس.

Even a molecule with nonpolar bonds, may have positively and negatively charged regions. Because electrons move constaltly, they (electrons) are not always symmetrically distributed in the molecule, they are accumulated in one part of the molecule or another. The result is **everchanging "hot spots"** of positive and negative charges that enable the atoms and molecules to stick **weakly** one to the other … These are called **van der Waals interaction** ….

Molecular Shape & Function شكل الجزيئات ووظيفتها

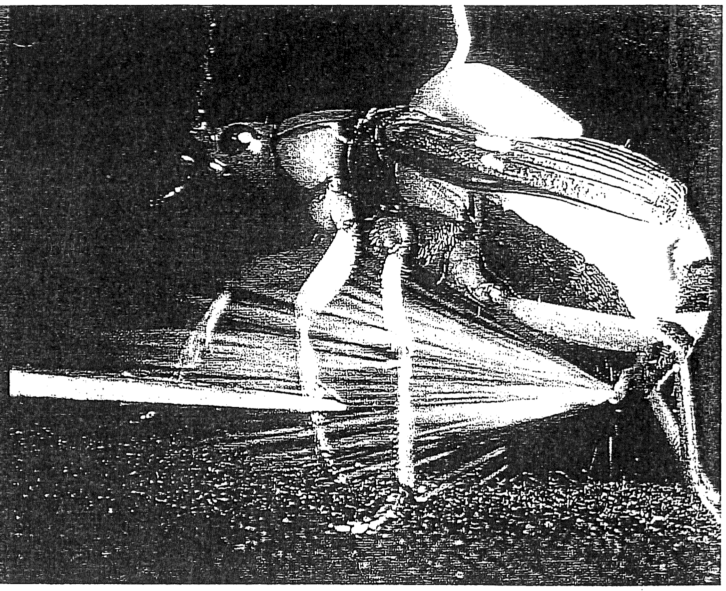
- لكل جزيء شكل وحجم .. الأمر المهم بالنسبة لوظيفته في الخلية الحية.
- الجزيء ذو الذرتين له صيغة خطية الشكل (H^2 or O^2) أما الجزيء بأكثر من ذرتين شكله أعقد من ذلك.
- للشكل أهميته في المنظومات الحية، إنه يحدد تمييز المنظومات لبعضها واستجاباتها لبعضها.
- الجزيئات المتطابقة شكلاً complementary shapes تستطيع الارتباط ببعضها .... الإندورفينات endorphenes (مسكنات ألم pain relievers) ومسكنات ألم أخرى، كالمورفين والهيروئين والأدوية الأفيونية الأخرى opiate drugs، ومستقبِلات الإندورفينات endorphins receptors على سطح الدماغ التي تُحاكي المورفين mimic endorphins



(a) **Structures of endorphin and morphine.** The boxed portion of the endorphin molecule (left) binds to receptor molecules on target cells in the brain. The boxed portion of the morphine molecule (right) is a close match.

(b) **Binding to endorphin receptors.** Endorphin receptors on the surface of a brain cell can bind to both endorphin and morphine.

2 The Chemical Context of Life



▲ **Figure 2.1 The bombardier beetle uses chemistry to defend itself.**

Key Concepts

2.1 Matter consists of chemical elements in pure form and in combinations called compounds
2.2 An element's properties depend on the structure of its atoms
2.3 The formation and function of molecules depend on chemical bonding between atoms
2.4 Chemical reactions make and break chemical bonds

Overview

Chemical Foundations of Biology

Like other animals, beetles have evolved structures and mechanisms that defend them from attack. The soil-dwelling bombardier beetle has a particularly effective mechanism for dealing with the ants that plague it. Upon detecting an ant on its body, this beetle ejects a spray of boiling hot liquid from glands in its abdomen, aiming the spray directly at the ant. (In **Figure 2.1**, the beetle aims its spray at a scientist's forceps.) The spray contains irritating chemicals that are generated at the moment of ejection by the explosive reaction of two sets of chemicals stored separately in the glands. The reaction produces heat and an audible pop.

Research on the bombardier beetle has involved chemistry, physics, and engineering, as well as biology. This is not surprising, for unlike a college catalog of courses, nature is not neatly packaged into the individual natural sciences. Biologists specialize in the study of life, but organisms and the world they live in are natural systems to which basic concepts of chemistry and physics apply. Biology is a multidisciplinary science.

This unit of chapters introduces key concepts of chemistry that will apply throughout our study of life. We will make many connections to the themes introduced in Chapter 1. One of those themes is the organization of life into a hierarchy of structural levels, with additional properties emerging at each successive level. In this unit, we will see how the theme of emergent properties applies to the lowest levels of biological organization—to the ordering of atoms into molecules and to the interactions of those molecules within cells. Somewhere in the transition from molecules to cells, we will cross the blurry boundary between nonlife and life. We begin by considering the chemical components that make up all matter. As Lydia Makhubu mentioned in the interview on pages 30 and 31, chemistry is an integral aspect of biology.

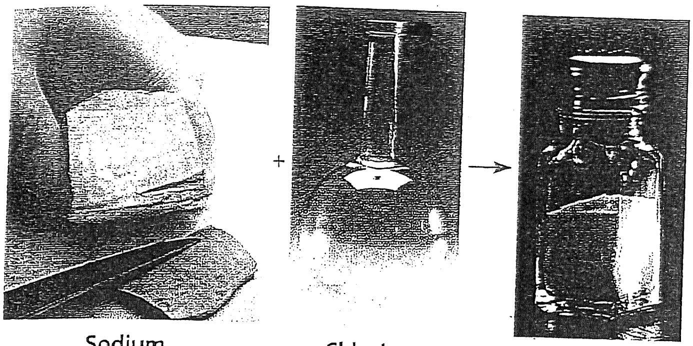
Concept 2.1

Matter consists of chemical elements in pure form and in combinations called compounds

Elements and Compounds

Organisms are composed of **matter**, which is anything that takes up space and has mass.* Matter exists in many diverse forms, each with its own characteristics. Rocks, metals, oils, gases, and humans are just a few examples of what seems an endless assortment of matter.

* Sometimes we substitute the term weight for mass, although the two are not identical. Mass is the amount of matter in an object, whereas the weight of an object is how strongly that mass is pulled by gravity. The weight of an astronaut walking on the moon is approximately 1/6 that on Earth, but his or her mass is the same. However, as long as we are earthbound, the weight of an object is a measure of its mass; in everyday language, therefore, we tend to use the terms interchangeably.



Sodium Chlorine Sodium chloride

▲ **Figure 2.2 The emergent properties of a compound.** The metal sodium combines with the poisonous gas chlorine to form the edible compound sodium chloride, or table salt.

Matter is made up of elements. An **element** is a substance that cannot be broken down to other substances by chemical reactions. Today, chemists recognize 92 elements occurring in nature; gold, copper, carbon, and oxygen are examples. Each element has a symbol, usually the first letter or two of its name. Some of the symbols are derived from Latin or German names; for instance, the symbol for sodium is Na, from the Latin word *natrium*.

A **compound** is a substance consisting of two or more different elements combined in a fixed ratio. Table salt, for example, is sodium chloride (NaCl), a compound composed of the elements sodium (Na) and chlorine (Cl) in a 1:1 ratio. Pure sodium is a metal and pure chlorine is a poisonous gas. When chemically combined, however, sodium and chlorine form an edible compound. This is a simple example of organized matter having emergent properties: A compound has characteristics different from those of its elements **(Figure 2.2)**.

Essential Elements of Life

About 25 of the 92 natural elements are known to be essential to life. Just four of these—carbon (C), oxygen (O), hydrogen (H), and nitrogen (N)—make up 96% of living matter. Phosphorus (P), sulfur (S), calcium (Ca), potassium (K), and a few other elements account for most of the remaining 4% of an organism's weight. **Table 2.1** lists by percentage the elements that make up the human body; the percentages for other organisms are similar. **Figure 2.3a** illustrates the effect of a deficiency of nitrogen, an essential element, in a plant.

Trace elements are those required by an organism in only minute quantities. Some trace elements, such as iron (Fe), are needed by all forms of life; others are required only by certain species. For example, in vertebrates (animals with backbones), the element iodine (I) is an essential ingredient of a hormone produced by the thyroid gland. A daily intake of only 0.15 milligram (mg) of iodine is adequate for normal

Table 2.1 Naturally Occurring Elements in the Human Body

Symbol	Element	Atomic Number (See p. 34)	Percentage of Human Body Weight
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1

Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

(a) Nitrogen deficiency

(b) Iodine deficiency

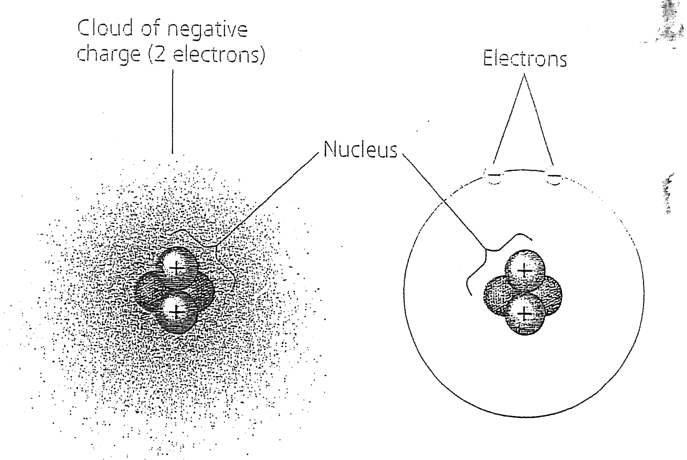
► **Figure 2.3 The effects of essential-element deficiencies. (a)** This photo shows the effect of nitrogen deficiency in corn. In this controlled experiment, the plants on the left are growing in soil that was fertilized with compounds containing nitrogen, while the soil on the right is deficient in nitrogen. **(b)** Goiter, an enlarged thyroid gland, is the result of a deficiency of the trace element iodine. The goiter of this Malaysian woman can probably be reversed by iodine supplements.

activity of the human thyroid. An iodine deficiency in the diet causes the thyroid gland to grow to abnormal size, a condition called goiter (Figure 2.3b). Where it is available, iodized salt has reduced the incidence of goiter.

Concept Check 2.1

1. Explain why table salt is a compound, while the oxygen we breathe is not.
2. What four chemical elements are most abundant in the food you ate yesterday?

For suggested answers, see Appendix A.



(a) This model represents the electrons as a cloud of negative charge, as if we had taken many snapshots of the 2 electrons over time, with each dot representing an electron's position at one point in time.

(b) In this even more simplified model, the electrons are shown as two small blue spheres on a circle around the nucleus.

▲ **Figure 2.4 Simplified models of a helium (He) atom.** The helium nucleus consists of 2 neutrons (brown) and 2 protons (pink). Two electrons (blue) move rapidly around the nucleus. These models are not to scale; they greatly overestimate the size of the nucleus in relation to the electron cloud.

Concept 2.2

An element's properties depend on the structure of its atoms

Each element consists of a certain kind of atom that is different from the atoms of any other element. An **atom** is the smallest unit of matter that still retains the properties of an element. Atoms are so small that it would take about a million of them to stretch across the period printed at the end of this sentence. We symbolize atoms with the same abbreviation used for the element made up of those atoms; thus, C stands for both the element carbon and a single carbon atom.

Subatomic Particles

Although the atom is the smallest unit having the properties of its element, these tiny bits of matter are composed of even smaller parts, called *subatomic particles*. Physicists have split the atom into more than a hundred types of particles, but only three kinds of particles are stable enough to be of relevance here: **neutrons, protons**, and **electrons.** Neutrons and protons are packed together tightly to form a dense core, or **atomic nucleus**, at the center of the atom. The electrons, moving at nearly the speed of light, form a cloud around the nucleus. **Figure 2.4** shows two models of the structure of the helium atom as an example.

Electrons and protons are electrically charged. Each electron has one unit of negative charge, and each proton has one unit of positive charge. A neutron, as its name implies, is electrically neutral. Protons give the nucleus a positive charge, and it is the attraction between opposite charges that keeps the rapidly moving electrons in the vicinity of the nucleus.

The neutron and proton are almost identical in mass, each about 1.7×10^{-24} gram (g). Grams and other conventional units are not very useful for describing the mass of objects so minuscule. Thus, for atoms and subatomic particles (and for molecules as well), we use a unit of measurement called the **dalton**, in honor of John Dalton, the British scientist who helped develop atomic theory around 1800. (The dalton is the same as the *atomic mass unit*, or *amu*, a unit you may have encountered elsewhere.) Neutrons and protons have masses close to 1 dalton. Because the mass of an electron is only about $1/2{,}000$ that of a neutron or proton, we can ignore electrons when computing the total mass of an atom.

Atomic Number and Atomic Mass

Atoms of the various elements differ in their number of subatomic particles. All atoms of a particular element have the same number of protons in their nuclei. This number of protons, which is unique to that element, is called the **atomic number** and is written as a subscript to the left of the symbol for the element. The abbreviation $_2He$, for example, tells us that an atom of the element helium has 2 protons in its nucleus. Unless otherwise indicated, an atom is neutral in electrical charge, which means that its protons must be balanced by an equal number of electrons. Therefore, the atomic number tells us the number of protons and also the number of electrons in an electrically neutral atom.

We can deduce the number of neutrons from a second quantity, the **mass number**, which is the sum of protons plus neutrons in the nucleus of an atom. The mass number is written