8.1.2 THE CHEMICAL ELEMENTS[M10]

8.1.2.1 Pure Substances

All the techniques described in the previous section, and others, can be used to separate the individual components of a mixture. Mixtures are characterised by a variable composition—the individual components may be present in any quantity, and the properties of any particular mixture will vary accordingly. Even so, mixtures may be **homogeneous**, in which case all parts of the mixture are the same, or **heterogeneous**, in which case the composition of the mixture may be non-uniform. **Solutions**, for example, are homogeneous mixtures with uniform composition. A piece of granite, however, is quite the opposite: heterogeneous and quite likely not exactly like any other piece of granite.

In contrast to mixtures, pure substances have definite compositions, and are always homogeneous. They are characterised by well-defined and consistent properties such as **boiling point**, **melting point**, **solubility** and **density**. Mixtures are invariably composed of two or more pure substances.

There are nonetheless, two kinds of pure substances: **elements** and **compounds**. In order to differentiate between these two types of substances, we need to note a unique characteristic of the substances we classify as elements.

8.1.2.1.1 Decomposition

All the changes we have considered so far—melting/freezing, boiling/condensing, sublimation/deposition, dissolution/crystallisation—are **physical changes**: ones in which there is no change in the chemical properties of a substance, only a change of state or form. These changes are usually readily reversible and thus temporary in nature.

Decomposition, however, is what is known as a **chemical change**: one in which a new substance or substances are formed with completely different properties from those of the starting materials. Chemical changes, by their very nature are generally permanent.

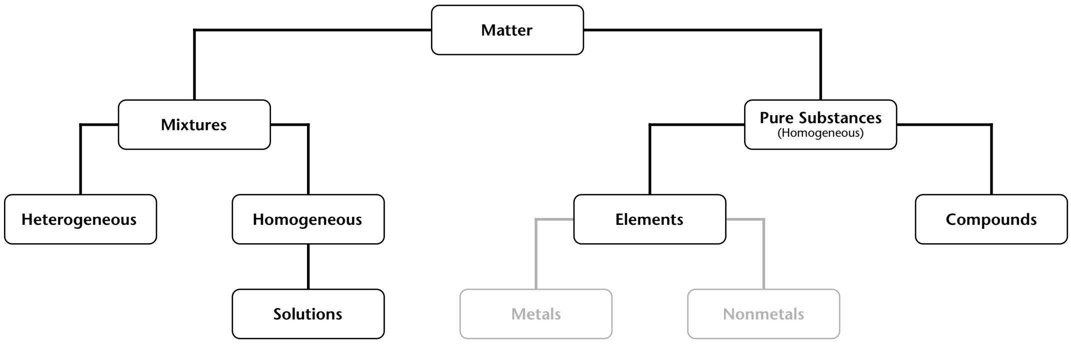
A type of chemical change in which one substance disappears and two or more substances are formed is called **decomposition** (If the change is simply brought about by heat, it is called **thermal decomposition**).

Observe the results of Experiments 10.1 – 10.5.

Elements, therefore, are those types of matter that cannot be further decomposed or changed into other elements by chemical methods. Compounds consist of chemically combined elements and can thus be decomposed into simpler substances by ordinary chemical means (but not by the physical means discussed in the previous section).

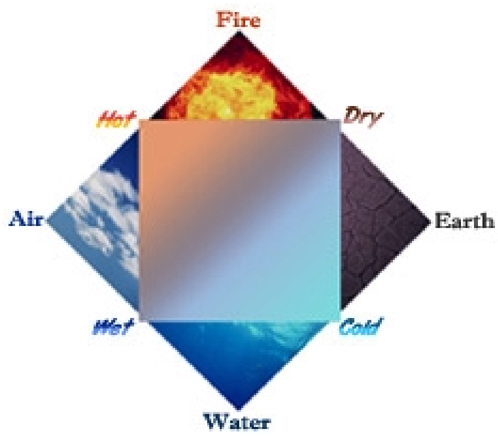
8.1.2.2 The Classification of Matter

Our observations so far are summarised by the following classification of matter.



8.1.2.3 Elements[1]

The concept of the existence of elements is not a new one. The Greek philosopher Empedocles (492–432 BC) believed that there were four elements—air, fire, water and earth. He believed that these elements reacted under various influences such as love, hate and anger, to form more complex substances. Others believed that these elements were connected with the qualities of hotness, coldness, wetness and dryness. Earth was cold and dry, air was hot and wet, fire was hot and dry, and water was cold and wet. If they had performed the experiment of heating wood, they would have concluded that wood consisted of the elements earth, water and air—that is, wood was transformed into charcoal, liquids and gaseous substances. Empedocles' theory was quite popular, but it had a number of problems. For example, no matter how many times you break a stone in half, the pieces never resemble any of the core elements of fire, air, water, or earth. Despite these problems, Empedocles' theory was an important development in scientific thinking because it was among the first to suggest that some substances that looked like pure materials, like stone, were actually made up of a combination of different *elements*.



The idea of elements as simple substances was first introduced by Robert Boyle (1627–1691), an Irishman who chose for his epitaph: "Father of Chemistry and Uncle of the Earl of Cork". In his book "The Sceptical Chymist", he says that there is no evidence in support of the view that there are only four elements and he suggests that chemists should regard as elements all those substances which they are unable to split up into two or more constituents. If a substance cannot be decomposed, it is to be considered an element and it will retain that title for just so long as it withstands efforts to decompose it.

The idea of elements as simple substances was first introduced by Robert Boyle (1627–1691), who suggested that an element should be regarded as such only if it could not be split up into two or more constituents. If a substance could not be

1 http://www.visionlearning.com/library/module_viewer.php?mid=49

decomposed, it is to be considered an element and it would retain that title for just so long as it withstood efforts to decompose it.

The acceptance of Boyle's views made the study of chemistry very much easier and marks the beginning of modern chemistry. For, once having accepted the idea of a simple substance, chemists could then seek and isolate the elements from which other materials were made. Lavoisier (1743–1794) listed an essentially correct table of 29 elements.

Observe the results of Experiments 10.6 – 10.11.

Since the acceptance of Boyle's concept of an element, 94 such substances have been isolated from the materials of the earth's crust and the atmosphere. Many of these were separated only after difficult, complex, and tedious operations. Every other substance that has been investigated can be broken down into one or more of these 94 elements—they are effectively the building blocks from which all matter has been built. It is not expected that any additional new elements will be isolated from the earth's crust, but another 22 artificial elements have been manufactured by changing the nucleus of one element into another.

Chemistry developed rapidly in the nineteenth century. No fewer than 57 of the 94 naturally occurring elements were identified in this century. Many reasons can be suggested for this but chief amongst them would be the failure of scientists in earlier centuries to develop a clear picture of what constituted a chemical change. Every chemical change was for them a special case having nothing in common with other chemical changes.

8.1.2.3.1 The Relative Abundance of Elements

The relative abundance (%) of the most common elements in the earth's crust, its atmosphere and life forms is listed in the following table.

Element†	Atmos-phere	Sea Water	Dry Soil	Dry Vegetation	Human Body
Nitrogen	75.5			1.6	2.4
Oxygen	23.2	85.8	47.3	42.9	65.0
Argon	1.3				
Hydrogen		10.7	0.2	6.1	10.2
Chlorine		2.1	0.1	0.2	0.3
Sodium		1.1	3.0	0.4	0.3
Calcium		0.1	3.5	0.6	1.6
Magnesium		0.1	2.2	0.4	0.1
Sulphur		0.1	0.1	0.4	0.2
Silicon			27.7	3.0	
Aluminium			7.8		
Iron			4.9		
Potassium			2.5	1.7	0.4
Titanium			0.5		
Carbon			0.2	44.3	17.5
Phosphorus			0.1	0.6	0.9

† Only elements comprising ate least 0.1% of the listed categories are included

8.1.2.4 The Periodic Table of Elements

The Periodic Table is Nature's Rosetta Stone. It reveals the organising principles of matter. At a fundamental level, all of chemistry is contained in the Periodic Table. The first organisation of the elements, in a fashion that resembled the modern Periodic Table, was described by Dmitry Mendeleyev (1834–1907) in 1869. Mendeleyev used his table as a means of illustrating recurring (*periodic*) trends in the properties of the elements known at the time. Without any knowledge of the structure of atoms, Mendeleyev's table ordered the elements on their respective atomic weights (essentially the respective weights of the individual atomic nuclei). Some 30 years later, J.J. Thomson (1856–1940) (who discovered the electron) suggested that the electronic configuration of atoms (the number of electrons 'orbiting' a nucleus) might account for the periodicity of the elements. It was not until 1914, and the X-ray studies of Henry Moseley (1887–1915[2]), that atomic numbers (the number of protons in the nucleus of an atom) were recognised as the basis for ordering the elements in the Periodic Table.

The modern Periodic Table comprises 18 Groups of elements: the 8 traditional Groups (1, 2, 13–18), plus the Transition Elements (Groups 3–12) and the [largely synthetic and radioactive] group of Lanthanides and Actinides. Each of the elements is given a name and a one- or two-letter abbreviation. Often this abbreviation is simply the first letter of the element; for example, hydrogen is abbreviated as H, and oxygen as O. Sometimes an element is given a two-letter abbreviation; for example, helium is He. When writing the abbreviation for an element, the first letter is always capitalised and the second letter (if there is one) is always lower case.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H**																	2 **He**
3 **Li**	4 **Be**											5 **B**	6 **C**	7 **N**	8 **O**	9 **F**	10 **Ne**
11 **Na**	12 **Mg**											13 **Al**	14 **Si**	15 **P**	16 **S**	17 **Cl**	18 **Ar**
19 **K**	20 **Ca**	21 **Sc**	22 **Ti**	23 **V**	24 **Cr**	25 **Mn**	26 **Fe**	27 **Co**	28 **Ni**	29 **Cu**	30 **Zn**	31 **Ga**	32 **Ge**	33 **As**	34 **Se**	35 **Br**	36 **Kr**
37 **Rb**	38 **Sr**	39 **Y**	40 **Zr**	41 **Nb**	42 **Mo**	43 **Tc**	44 **Ru**	45 **Rh**	46 **Pd**	47 **Ag**	48 **Cd**	49 **In**	50 **Sn**	51 **Sb**	52 **Te**	53 **I**	54 **Xe**
55 **Cs**	56 **Ba**	*	72 **Hf**	73 **Ta**	74 **W**	75 **Re**	76 **Os**	77 **Ir**	78 **Pt**	79 **Au**	80 **Hg**	81 **Tl**	82 **Pb**	83 **Bi**	84 **Po**	85 **At**	86 **Rn**
87 **Fr**	88 **Ra**	**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ds**	111 **Rg**	112 **Uub**	113 **Uut**	114 **Uuq**	115 **Uup**	116 **Uuh**		

* Lanthanides	57 **La**	58 **Ce**	59 **Pr**	60 **Nd**	61 **Pm**	62 **Sm**	63 **Eu**	64 **Gd**	65 **Tb**	66 **Dy**	67 **Ho**	68 **Er**	69 **Tm**	70 **Yb**	71 **Lu**
** Actinides	89 **Ac**	90 **Th**	91 **Pa**	92 **U**	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

[2] Henry Moseley was killed in action at Gallipoli. It was widely believed that, had he lived, he would have been awarded the Nobel prize for his work. Moseley's death in combat is often cited as the reason why the British government subsequently forbade its scientists from entering combat service.