Why Icebergs Float

Morris, Andrew

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Appendix: Atoms, Elements and Molecules

Some underlying concepts crop up time and again in discussion and throughout this book. Of these the most frequent are those that describe the make-up of substances. They occur whether we are talking about haemoglobin in blood, cochineal in food colouring or oxygen in the air. You may have a rough idea of the meaning of words such as element, molecule and atom, but the precise distinctions may need clarifying. As Julie once put it memorably, when a discussion about the nervous system was in full swing: ‘Andrew, before we go any further: what exactly is a molecule?’ ‘Is it different from an element?’ queried Sarah, underlining the general sense of confusion. In this Appendix we attempt to clarify these differences in meaning, starting with what is closest to everyday life: the substances we hear about or read about on labels.

Substances and mixtures

Most things we are familiar with in everyday life are mixtures of different substances: cough syrup, jam or air, for example. Underneath this apparent variety lies an important unifying simplicity: every kind of ‘stuff’ (or, more properly, material) is made exclusively of atoms.

In mixtures, the blend of ingredients can be varied – as any maker of jam knows. There is a different percentage of sugar in different jams, for example. The word substance, on the other hand, is reserved in science for materials that have a fixed composition: the blend of ingredients doesn’t vary. This means the atoms that make up a substance are always in the same proportion. Salt, for example, is a combination of sodium and chorine, always in an exact 1:1 ratio, and carbon dioxide always comprises two oxygen atoms for each carbon atom. In a substance, these atoms are chemically bonded to one another.
Compounds

A jar of strawberry jam contains pectin, a car battery contains hydrochloric acid, the air we breathe out contains carbon dioxide. These are all examples of compounds. They are made up (or compounded) of more than one kind of atom. Most substances are in fact compounds. However, a few substances are not compounded, but are made up of only one type of atom – a bar of gold, for example.

Elements

Elements are substances that are made of one kind of atom; carbon, mercury and hydrogen, for example, are all elements and as such cannot be broken down into simpler components. There are over 100 elements, all charted in the famous Periodic Table. Only 92 elements are found in nature, and these are the ingredients from which everything we can see is made, including our own bodies. There are also about 25 synthetic elements, artificially made in our nuclear reactors and in the laboratory, for example plutonium. Clearly elements differ dramatically one from another. Carbon is a hard solid, mercury a liquid metal and hydrogen an invisible gas. The difference in their properties lies in the make-up of the atoms of the various elements.

Atoms

The atom is the basic unit that distinguishes one element from another. The overall architecture of all atoms is the same: each is composed of a number of particles arranged in the same way. But the number of particles in the atoms of the various elements does differ. In all atoms there is a number of positively charged particles (called protons), all clustered together in a hard kernel called a nucleus. An equal number of negatively charged particles (called electrons) is arranged well away from the nucleus, and these particles are in rapid motion around it. A carbon atom, for example, has six protons and an equal number of electrons, an atom of oxygen has eight protons and electrons and hydrogen has only one of each. The equal number of positive and negative particles means that matter is normally uncharged, or neutral, overall. The nucleus also contains a number of uncharged particles called neutrons, clustered together with the protons.

Atoms are the smallest units of matter in everyday circumstances. However, in the form in which we normally encounter things, they are
often aggregated into larger units. In metals and minerals, the atoms are held together by electrical attraction. In many other substances, including most biological ones, the atoms are bonded to one another in the form of molecules.

**Molecules**

Molecules are the smallest unit in which many substances normally exist. A molecule is a group of atoms held together by bonds; carbon dioxide ($\text{CO}_2$) and water ($\text{H}_2\text{O}$) are familiar examples. In general molecules contain atoms of different elements – such as carbon, hydrogen and oxygen – but some, like the oxygen molecule we breathe ($\text{O}_2$), consist simply of atoms of the same type. Molecules can be as small as just two atoms bonded together or may contain dozens or hundreds of atoms. In living systems some types of molecules (proteins and DNA, for example) run to many thousands of atoms.

The majority of substances we encounter in this book are made up of molecules. Foods, for example, contain proteins and carbohydrates, which are large molecules containing many atoms. Other bodily materials, such as neurotransmitters, amino acids and sugars are also molecules. Two examples of molecular structure are illustrated here (Fig. A.1), using models in which the rounded shapes represent atoms. White ones represent hydrogen atoms, red are oxygen, black are carbon and blue are nitrogen.

**Ions**

An ion is an atom or molecule that is electrically charged because of an imbalance in the number of charged particles of which it is made. It has either more or fewer electrons than protons, and may thus be negatively or positively charged by the gain or loss of one or more electrons. For example, an ion of the calcium atom has two fewer electrons and is denoted by $\text{Ca}^{2+}$ or $\text{Ca}^{++}$; while an ion of the atom chlorine has one extra electron and is denoted by $\text{Cl}^-$.

A few substances mentioned in the book are not structured as discrete molecules, but as an extended array of ions. In common salt, sodium chloride, for example, the ions are held together, as in other minerals, by electrical attraction (Fig. A.2). The sodium is in the form of a positively charged ion ($\text{Na}^+$) and the chloride a negatively charged ion ($\text{Cl}^-$). The two types of ion are attracted to each other, holding the substance together.
Fig. A.1  Models of molecules

Fig. A.2  Model of sodium chloride (common salt) (sodium is violet, chlorine is green)