Chapter One

Basic Concepts of Matter

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Volcano Burning

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Three States of Matter

Solid, liquid, and gas states

Water can be found in the solid, liquid, and vapor (gaseous) forms simultaneously.

David Schultz/Getty Images

Chemical Reactions

→ **Fig. 1.3**
The green color of the Statue of Liberty results from the reaction of copper with the components of air.

Andy Levin/Photo Researchers

Chemical Substances

"Good" versus "Bad" Properties for a Chemical Substance

It is important not to judge the significance or usefulness of a chemical substance on the basis of just one or two of the many chemical and physical properties it exhibits. Possession of a "bad" property, such as toxicity or a strong noxious odor, does not mean that a chemical substance has nothing to contribute to the betterment of human society.

A case in point is the substance carbon monoxide. Everyone knows that it is a gaseous air pollutant present in automobile exhaust and cigarette smoke and that it is toxic to human beings. For this reason, some people automatically label carbon monoxide a "bad" substance, a substance we do not need or want.

Indeed, carbon monoxide is toxic to human beings. It impairs human health by reducing the oxygen-carrying capacity of the blood. Carbon monoxide does this by interacting with the hemoglobin in red blood cells in a way that prevents the hemoglobin from distributing oxygen throughout the body. Someone who dies from carbon monoxide poisoning actually dies from lack of oxygen.

The fact that carbon monoxide is colorless, odorless, and tasteless is very significant. Because of these properties, carbon monoxide gives no warning of its initial presence. There are several other common air pollutants that are more toxic than carbon monoxide. However, they have properties that give warning of their presence and hence they are not considered as "dangerous" as carbon monoxide.

Despite its toxicity, carbon monoxide plays an important role in the maintenance of the high standard of living we now enjoy. Its contribution lies in the field of iron metallurgy and the production of steel. The isolation of iron from iron ores, necessary for the production of steel, involves a series of high-temperature reactions, carried out in a blast furnace, in which the iron content of molten iron ores reacts with carbon monoxide. These reactions release the iron from its ores. The carbon monoxide needed in steel making is obtained by reacting coke (a product derived by heating coal to a high temperature without air being present) with oxygen.

The industrial consumption of the metal iron, both in the United States and worldwide, is approximately ten times greater than that of all other metals combined. Steel production accounts for nearly all of this demand for iron. Without steel, our standard of living would drop dramatically, and carbon monoxide is necessary for the production of steel.

Is carbon monoxide a "good" or a "bad" chemical substance? The answer to this question depends on the context in which the carbon monoxide is encountered. In terms of air pollution, it is a "bad" substance. In terms of steel making, it is a "good" substance. A similar "good–bad" dichotomy exists for almost every chemical substance.

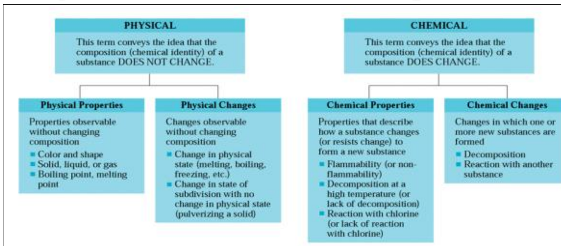
Changes of States

- The melting of ice cream is a physical change involving a change of state; solid turns to liquid.

Rusting is a chemical reaction

As a result of chemical change, bright steel girders become rusty when exposed to moist air.

Physical Vs. Chemical changes



Magnetic separations

Fig. 1.6a

James Scherer

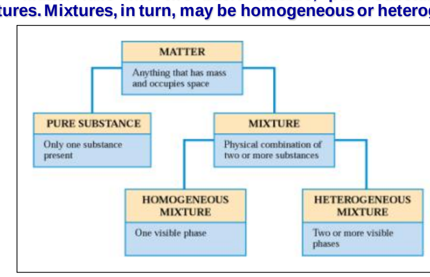
James Scherer

(a) **A magnet and a mixture consisting of potassium dichromate (orange crystals) and iron fillings.**

(b) The magnet can be used to separate the iron fillings from the potassium dichromate.

Classification of matter

Fig 1.7 Matter falls into two basic classes; pure substances and mixtures. Mixtures, in turn, may be homogeneous or heterogeneous.



Pure substances

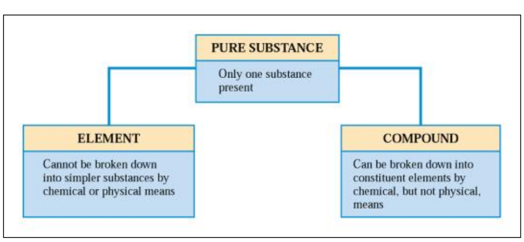
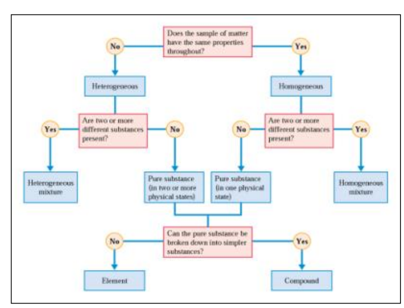


Fig 1.8 A pure substance can be either an element or a compound.

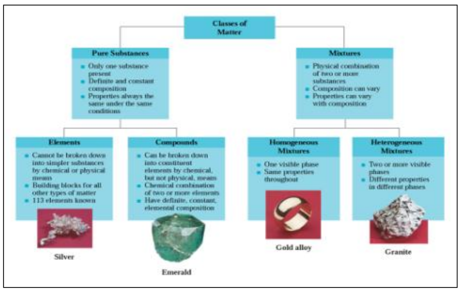
Classification of matter cont'd

→ **Fig. 1.9 Questions used in classifying matter into various categories.**



Classification of matter cont'd

→ *CAG 1.2*

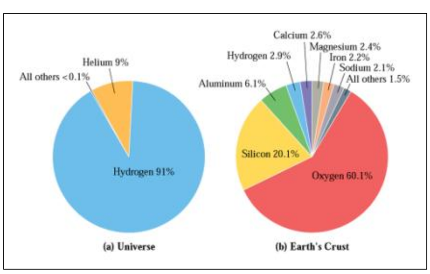


Elements and properties

← Fig. 1.10 Outward physical appearance of naturally occurring elements

Abundance of Elements

→ **Abundance of elements in the universe and in Earth's crust (in atom percent)**



Elements of human body

	Hydrogen	Oxygen	Carbon	Nitrogen
Water	x	x		
Carbohydrate	x	x	x	
Fat	x	x	x	
Protein	x	x	x	x

← **C.C. 1.2 Elemental Composition of the Human Body**

Naming elements

Ac	actinium	Gd	gadolinium	Po	polonium
Ag	silver*	Ge	germanium	Pr	praseodymium
Al	aluminum	H	hydrogen	Pt	platinum
Am	americium	He	helium	Pu	plutonium
Ar	argon	Hf	hafnium	Ra	radium
As	arsenic	Hg	mercury*	Rb	rubidium
At	astatine	Ho	holmium	Re	rhenium
Au	gold*	Hs	hassium	Rf	rutherfordium
B	boron	I	iodine	Rg	roentgenium
Ba	barium	In	indium	Rh	rhodium
Be	beryllium	Ir	iridium	Rn	radon
Bh	bohrium	K	potassium*	Ru	ruthenium
Bi	bismuth	Kr	krypton	S	sulfur
Bk	berkelium	La	lanthanum	Sb	antimony*
Br	bromine	Li	lithium	Sc	scandium
C	carbon	Lr	lawrencium	Se	selenium
Ca	calcium	Lu	lutetium	Sg	seaborgium
Cd	cadmium	Md	mendelevium	Si	silicon
Ce	cerium	Mg	magnesium	Sm	samarium
Cf	californium	Mn	manganese	Sn	tin*
Cl	chlorine	Mo	molybdenum	Sr	strontium
Cm	curium	Mt	meitnerium	Ta	tantalum
Co	cobalt	N	nitrogen	Tb	terbium
Cr	chromium	Na	sodium*	Tc	technetium
Cs	cesium	Nb	niobium	Te	tellurium
Cu	copper*	Nd	neodymium	Th	thorium
Db	dubnium	Ne	neon	Ti	titanium
Ds	darmstadtium	Ni	nickel	Tl	thallium
Dy	dysprosium	No	nobelium	Tm	thulium
Er	erbium	Np	neptunium	U	uranium
Es	einsteinium	O	oxygen	V	vanadium
Eu	europium	Os	osmium	W	tungsten*
F	fluorine	P	phosphorus	Xe	xenon
Fe	iron*	Pa	protactinium	Y	yttrium
Fm	fermium	Pb	lead*	Yb	ytterbium
Fr	francium	Pd	palladium	Zn	zinc
Ga	gallium	Pm	promethium	Zr	zirconium

Only 111 elements are listed in this table. Elements 112–115 discovered (synthesized) in the period 1996–2004 are yet to be named.

*These elements have symbols that were derived from non-English names.

← **Table 1.1**

Can we see atoms?

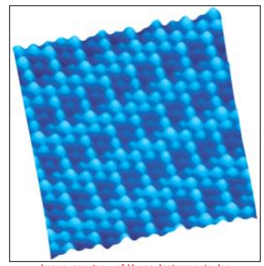
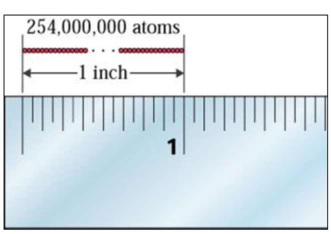


Image courtesy of Veeco Instruments Inc.

← **Fig. 1.12**
A computer reconstruction of the surface of a sample of graphite (carbon) as observed with a scanning tunneling microscope. The image reveals the regular pattern of individual carbon atoms. The color was added to the image by computer.

Size of atoms

→ **Fig. 1.13**
254 million atoms arranged in a straight line would extend a distance of approximately 1 inch.



Molecular structure

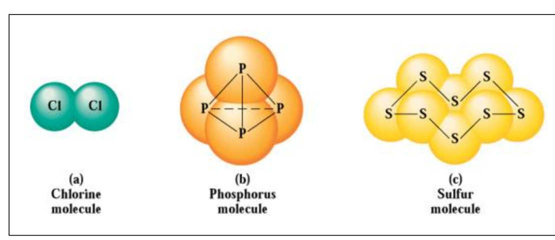
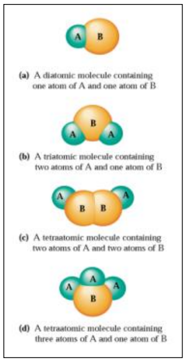


Fig 1.14 Molecular structure of (a) chlorine, (b) phosphorus, and (c) sulfur

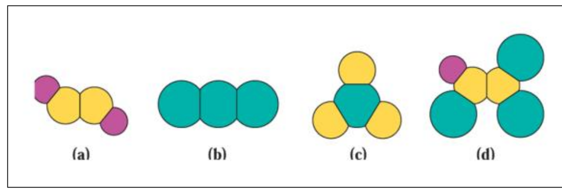
Basic Concepts of Matter cont'd



← **Fig. 1.15**
Depictions of various simple heteroatomic molecules using models. Spheres of different sizes and colors represent different kinds of atoms.

Homo- and heteo-atomic molecules

Example 1.2
Classify each of the following molecules as (1) diatomic, triatomic, etc. (2) homoatomic or heterotomic and (3) representing an element of a compound.



What type of molecules?

Practice Example 1.2
Classify each of the following molecules as (1) diatomic, triatomic, etc. (2) homoatomic or heterotomic and (3) representing an element of a compound.