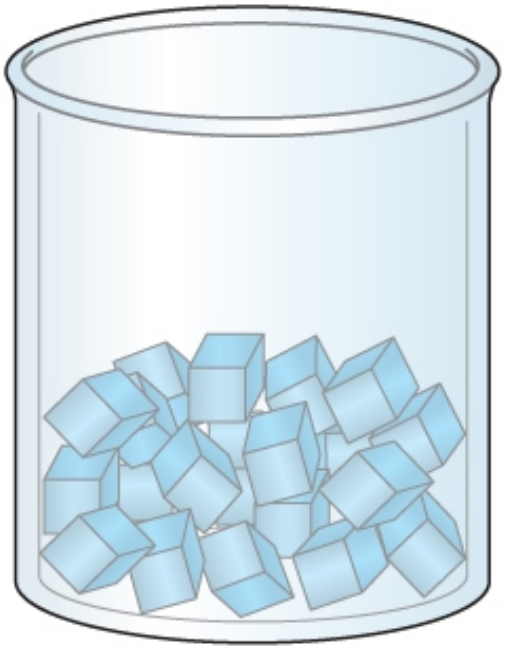
Chapter 4 – Matter

- Chemistry – The study of Matter

- Matter – any substance that has mass and occupies volume

- States of Matter
  - Solid – definite shape and volume
  - Liquid – definite volume, but no definite shape
  - Gas – no definite shape or volume

(a)

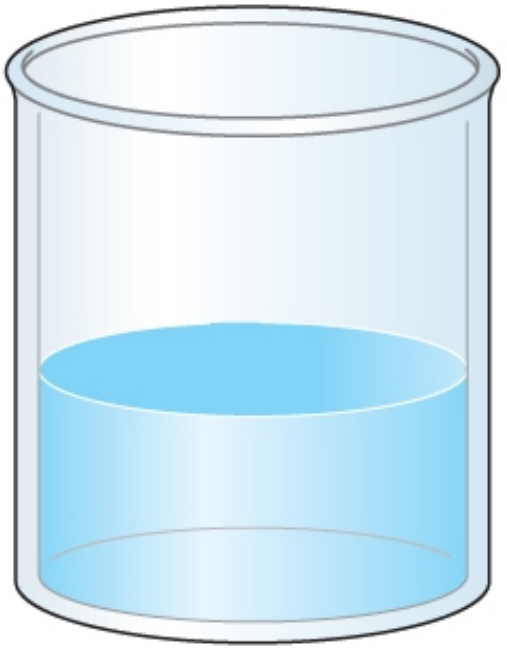


Solid

Definite shape

Definite volume

(b)

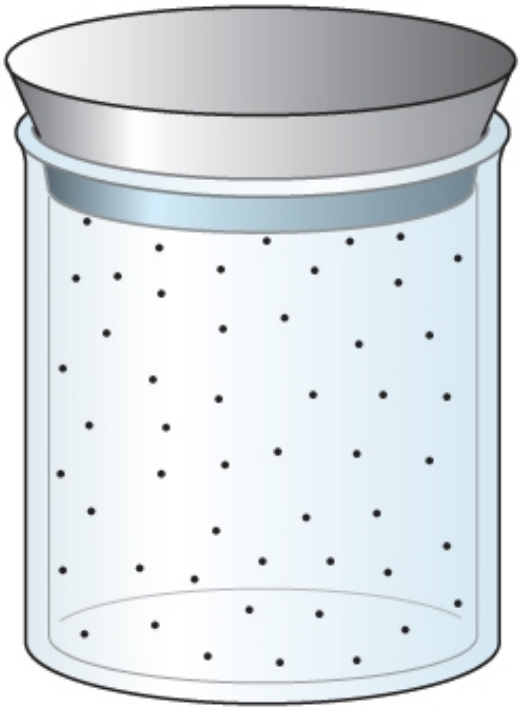


Liquid

Indefinite shape

Definite volume

(c)



Gas

Indefinite shape

Indefinite volume

- Physical Properties – Can be observed without affecting or changing the substance
  - color, odor, taste, size, state, boiling point, melting point, density, hardness

- Chemical Properties – How a substance changes, or resists changing, into another substance
  - oxidation, rusting, combustion, decomposition

- Intensive properties – do not depend on the amount of a substance
  - temperature, color, melting/boiling point, density

- Extensive properties – do depend on the amount of a substance
  - mass, volume, length, shape

TABLE 4.1 Selected Physical and Chemical Properties of Water

Physical Properties	Chemical Properties
1. Colorless 2. Odorless 3. Boiling point = 100°C 4. Freezing point = 0°C 5. Density = 1.000 g/mL at 4°C	1. Reacts with bromine to form a mixture of two acids. 2. Can be decomposed by means of electricity to form hydrogen and oxygen. 3. Reacts vigorously with the metal sodium to produce hydrogen. 4. Does not react with gold even at high temperatures. 5. Reacts with carbon monoxide at elevated temperatures to produce carbon dioxide and hydrogen.

- Physical changes – No change in composition; no bonds are broken and/or formed
  - changes in size, shape, smoothness, state of matter

- Chemical changes – Changes in chemical composition; bonds are broken and/or formed
  - oxidation, combustion, decomposition

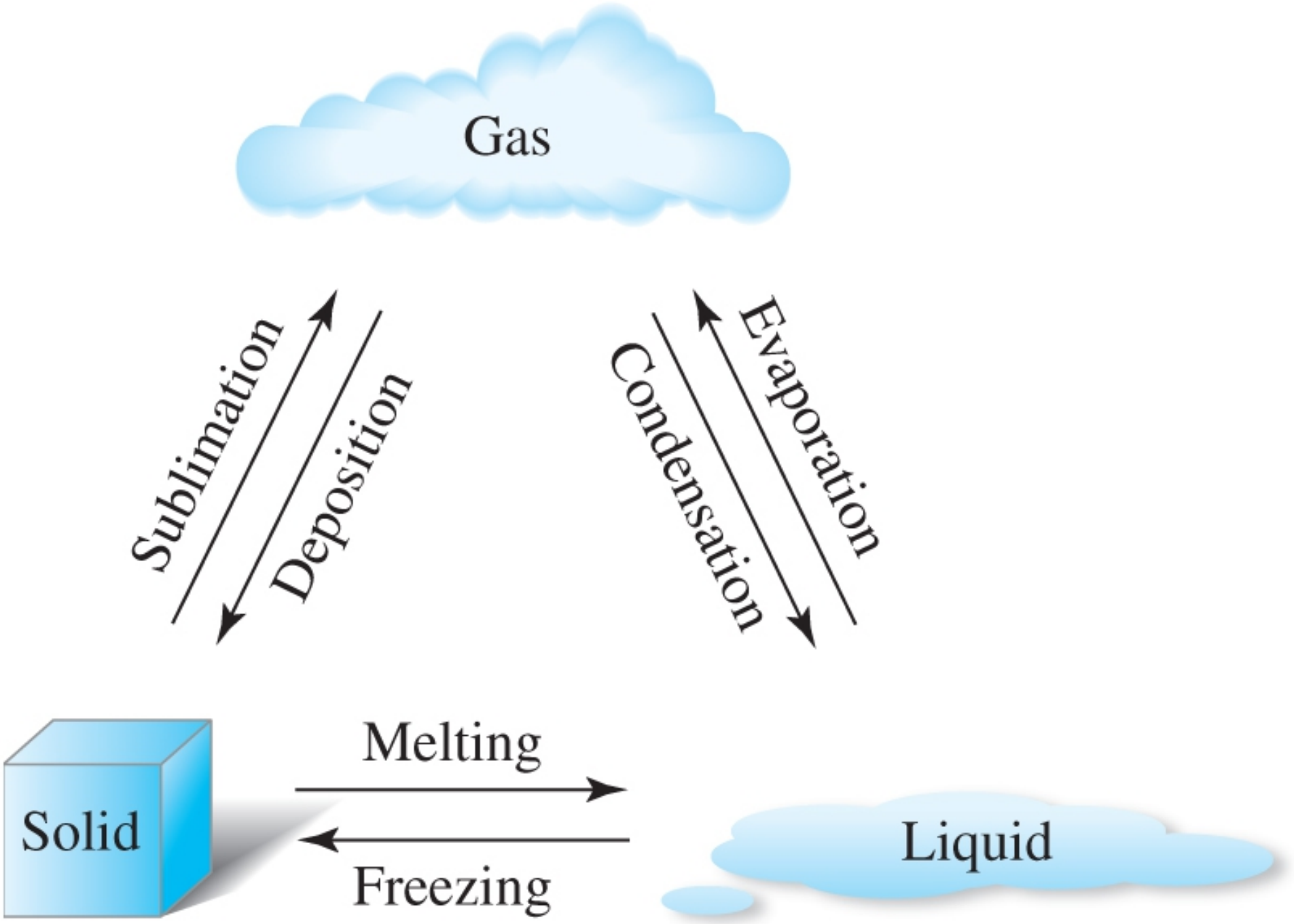
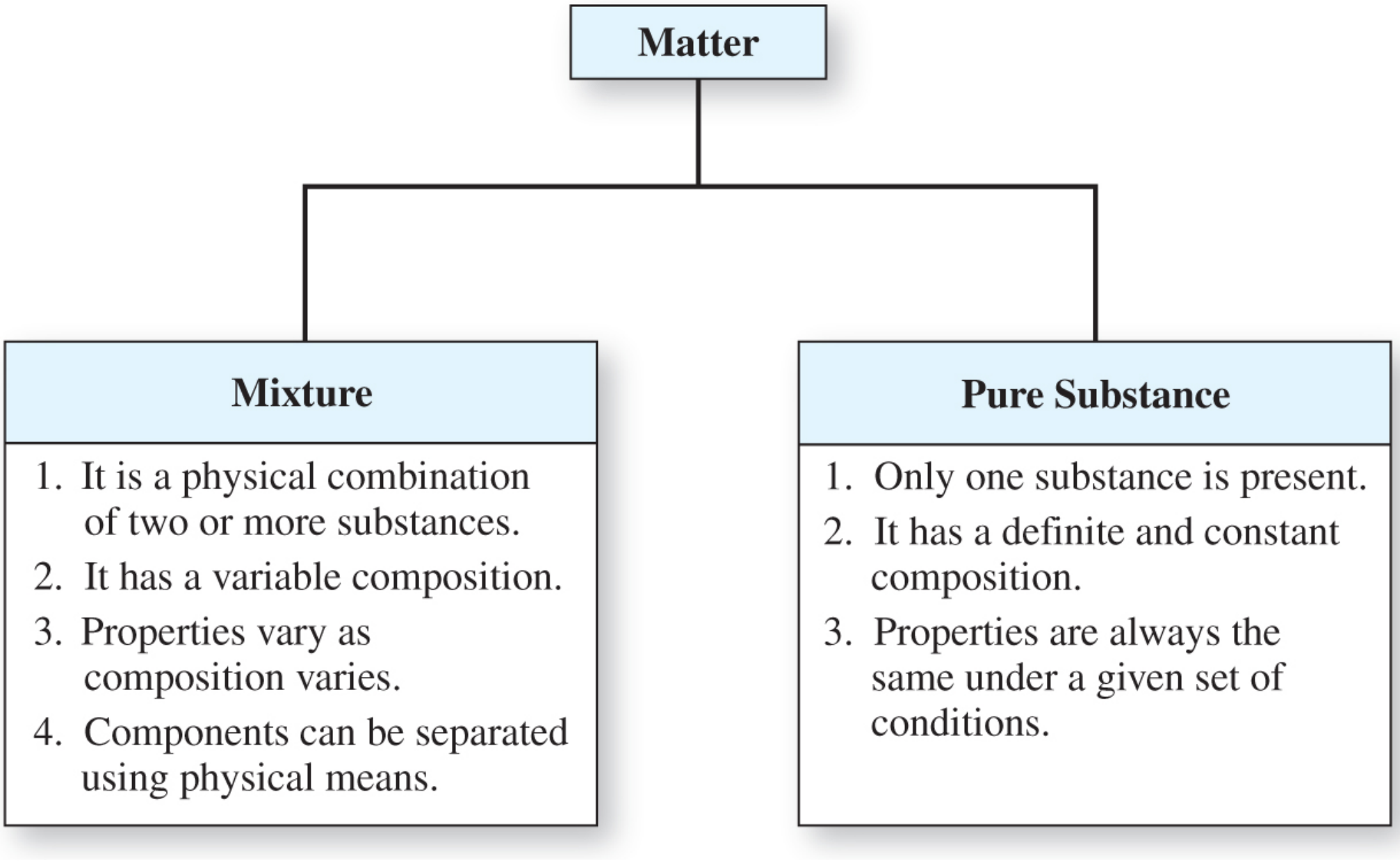


TABLE 4.2 Classification of Changes as Physical or Chemical

Change	Classification
Rusting of iron	chemical
Melting of snow	physical
Sharpening a pencil	physical
Digesting food	chemical
Taking a bite of food	physical
Burning gasoline	chemical
Slicing an onion	physical
Detonation of dynamite	chemical
Souring of milk	chemical
Breaking of glass	physical



Matter can be divided into Pure Substances and Mixtures:

- Pure substances – Can't be broken down by physical means into simpler substances
  - Elements – Simplest stable form of matter; can't be broken down chemically.
  - Compounds – Can be broken down by chemical means into other compounds or elements.

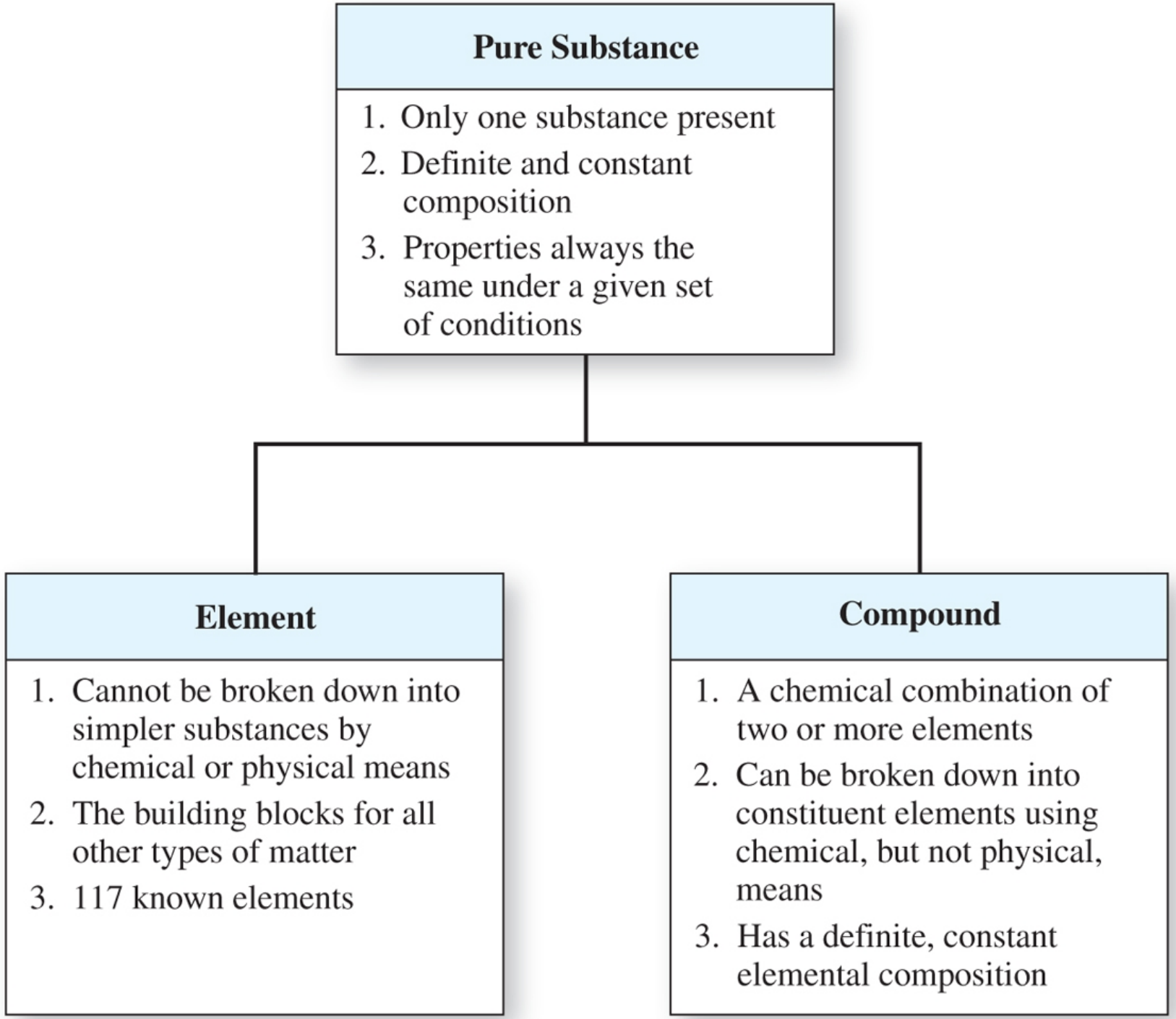


TABLE 4.3 The Chemical Symbols for the Elements

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

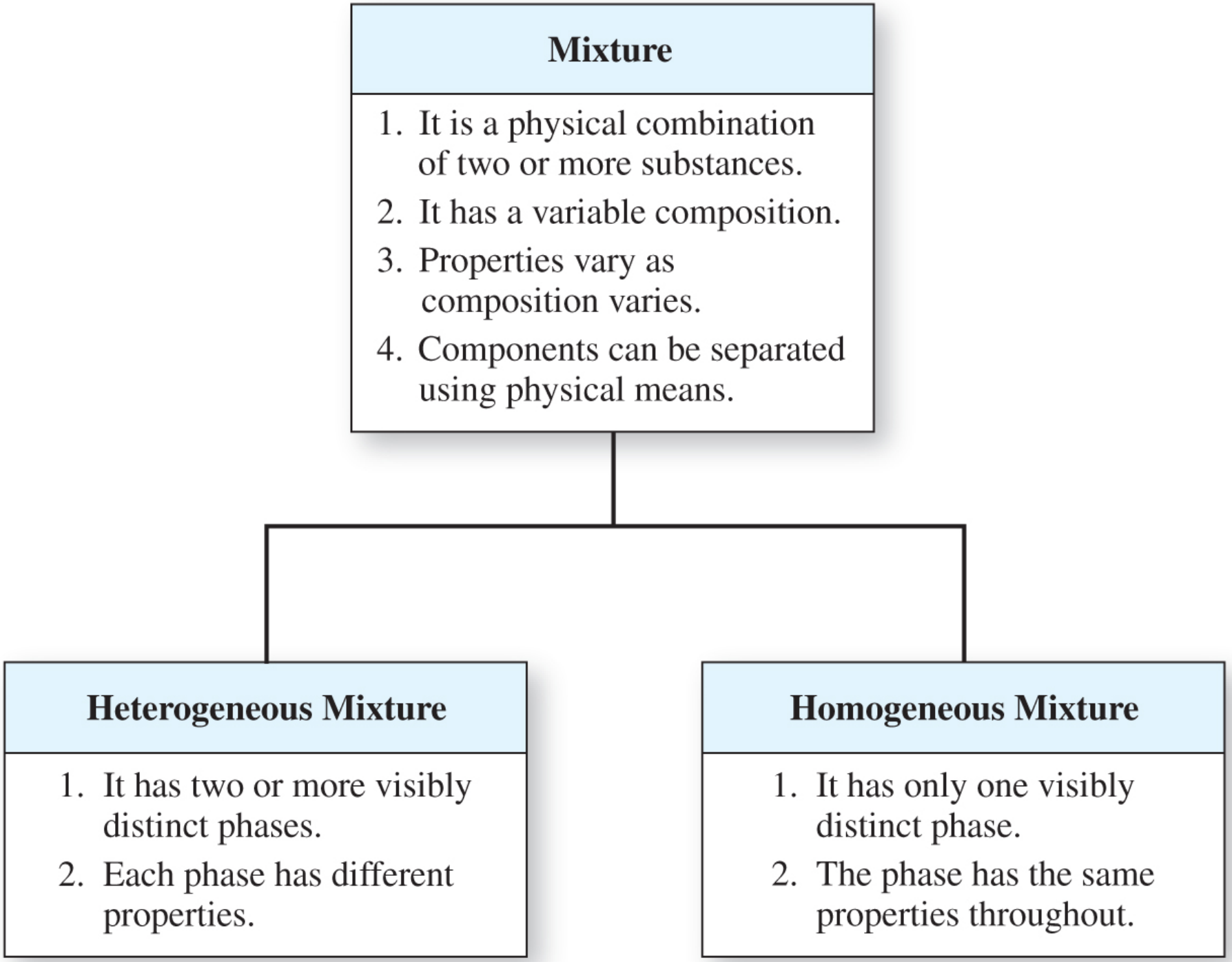
Only 111 elements are listed in this table. Elements 112–116 and 118, discovered (synthesized) in the period 1996–2006, are yet to be named.

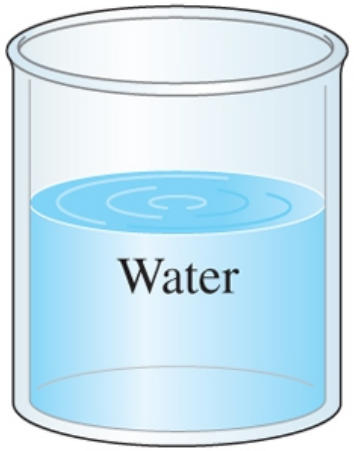
**These elements have symbols that were derived from non-English sources.*

TABLE 4.4 Elements Whose Chemical Symbols Are Derived from a Non-English Name of the Element

English Name of Element	Non-English Name of Element	Chemical Symbol
	Chemical Symbols From Latin	
Antimony	stibium	Sb
Copper	cuprum	Cu
Gold	aurum	Au
Iron	ferrum	Fe
Lead	plumbum	Pb
Mercury	hydragyrum	Hg
Potassium	kalium	K
Silver	argentum	Ag
Sodium	natrium	Na
Tin	stannum	Sn
	Chemical Symbol From German	
Tungsten	wolfram	W

- Mixtures – Physical combinations of two or more pure substances:
  - Homogeneous mixtures – Uniformly mixed on a sub-microscopic scale; one phase throughout:
    - sugar water, air, metal alloys
  - Heterogeneous mixtures – Physical mixtures with regions of different composition and/or phases; often different regions visible with the naked eye:
    - soup, dirt, blood, homogenized milk





Chemically homogeneous
Physically homogeneous

One substance and one phase

(a) Pure water

Chemically heterogeneous
Physically homogeneous

Two substances and one phase

(b) Sugar water

Chemically heterogeneous
Physically heterogeneous

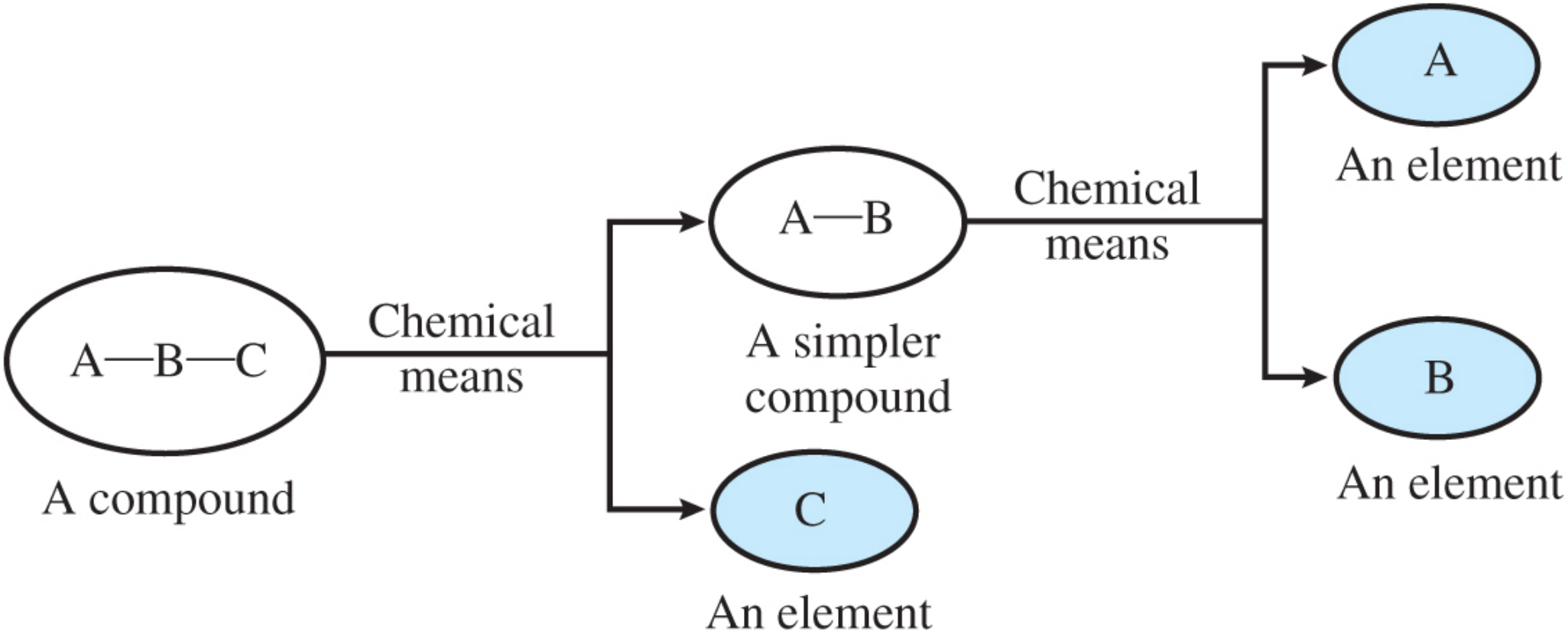
Two substances and two phases

(c) Oil and water

Chemically homogeneous
Physically heterogeneous

One substance and two phases

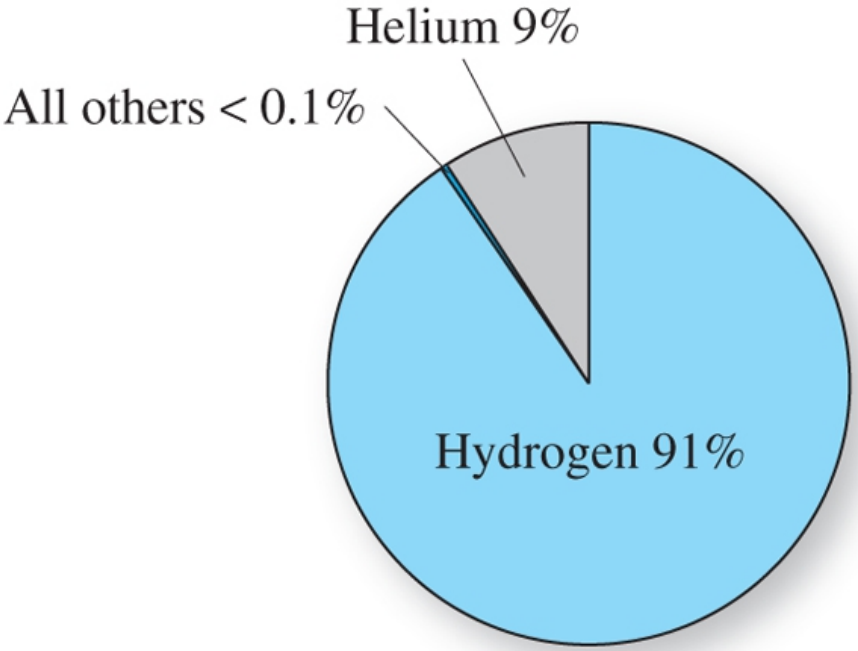
(d) Ice and water



Elements

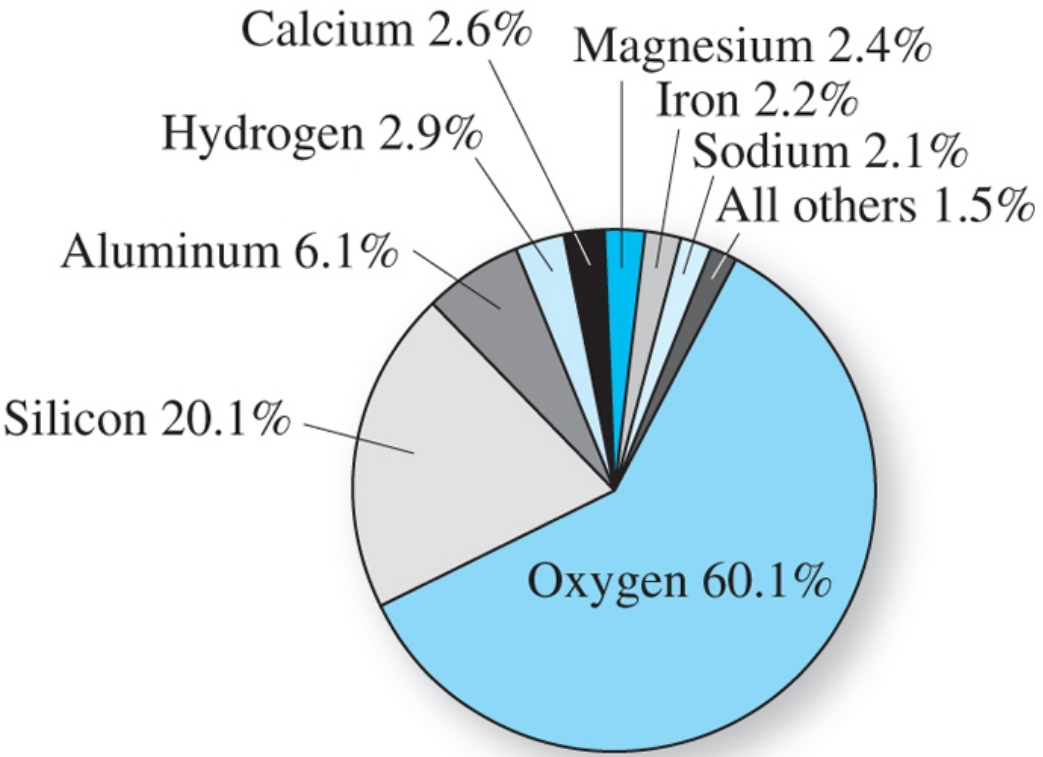
- Chemical symbols – used to represent elements
  - One or two letters, first is capitalized

- Atom
  - Smallest particle of an element that has the properties of that element
  - Cannot be broken down by chemical means
  - ~10^{-10} m in diameter
  - ~10^{-21} -10^{-23} grams mass
  - There are about 5 x 10^{21} atoms in a single drop of water



Universe

(a)



Earth's crust

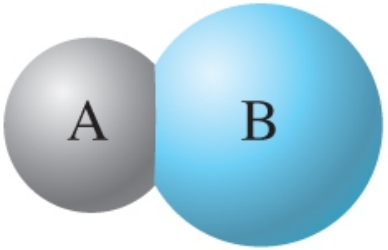
(b)

Molecules

- Usually only non-metals form molecules
- Two or more atoms tied together by molecular (covalent) bonds
- Have a fixed number of atoms in a set spatial arrangement
  - H_2O, CO_2, CO, CH_4, $C_6H_{13}OH$

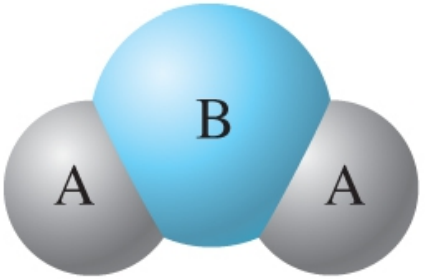
Molecules

- Binary – composed of only two elements:
  - H_2O, CO_2, CO, CH_4
- Diatomic – composed of only two atoms:
  - H_2, O_2, Cl_2, CO
- Homoatomic – composed of only one element:
  - H_2, O_2, O_3, S_8
- Heteroatomic – composed of different elements:
  - H_2O, CO_2, CO, CH_4, $C_6H_{13}OH$



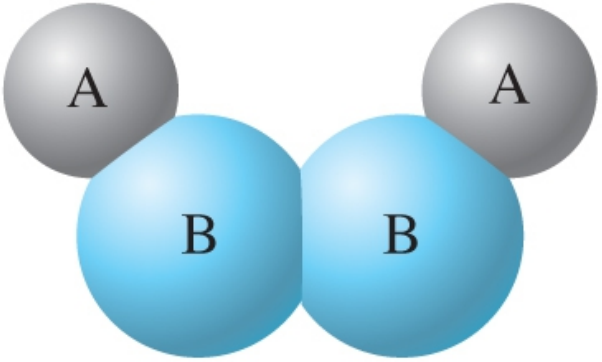
A diatomic molecule containing one atom of A and one atom of B

(a)



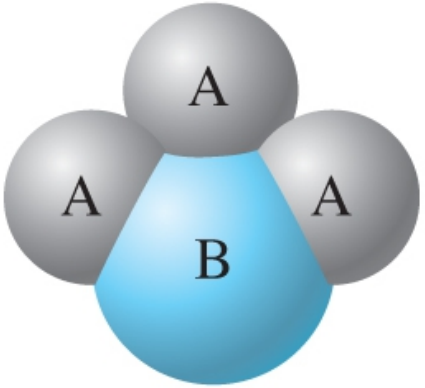
A triatomic molecule containing two atoms of A and one atom of B

(b)



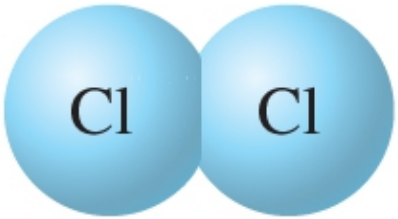
A tetratomic molecule containing two atoms of A and two atoms of B

(c)



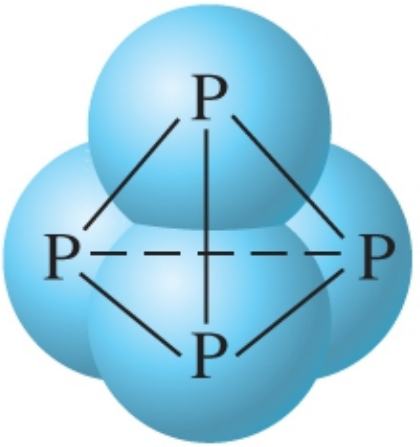
A tetratomic molecule containing three atoms of A and one atom of B

(d)



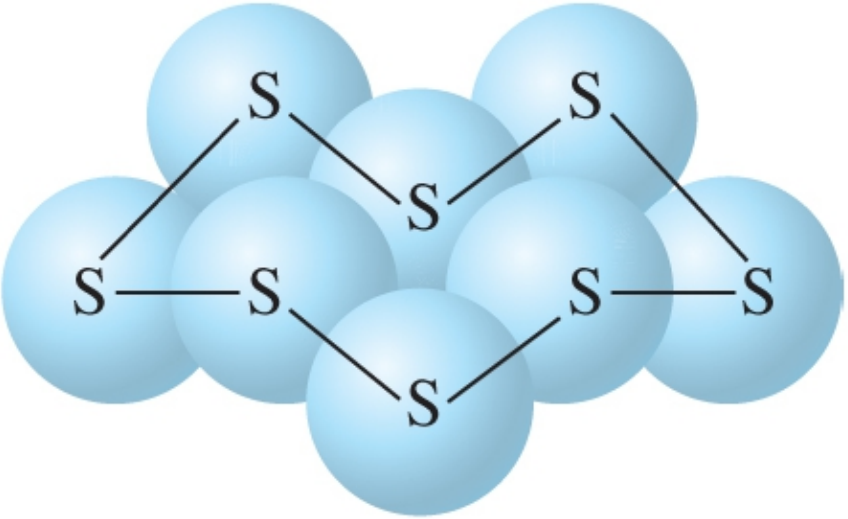
Two atoms

(a)



Four atoms

(b)



Eight atoms

(c)

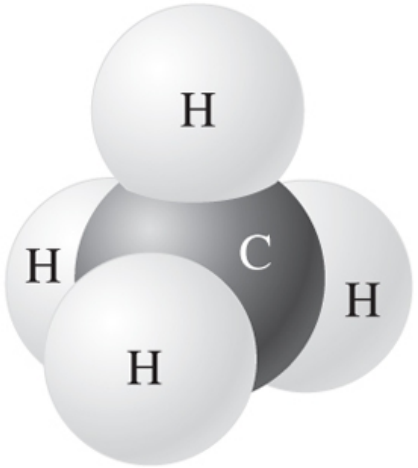
Ionic Compounds

- Formed between metals and non-metals, and also with polyatomic ions (electrically charged molecules)

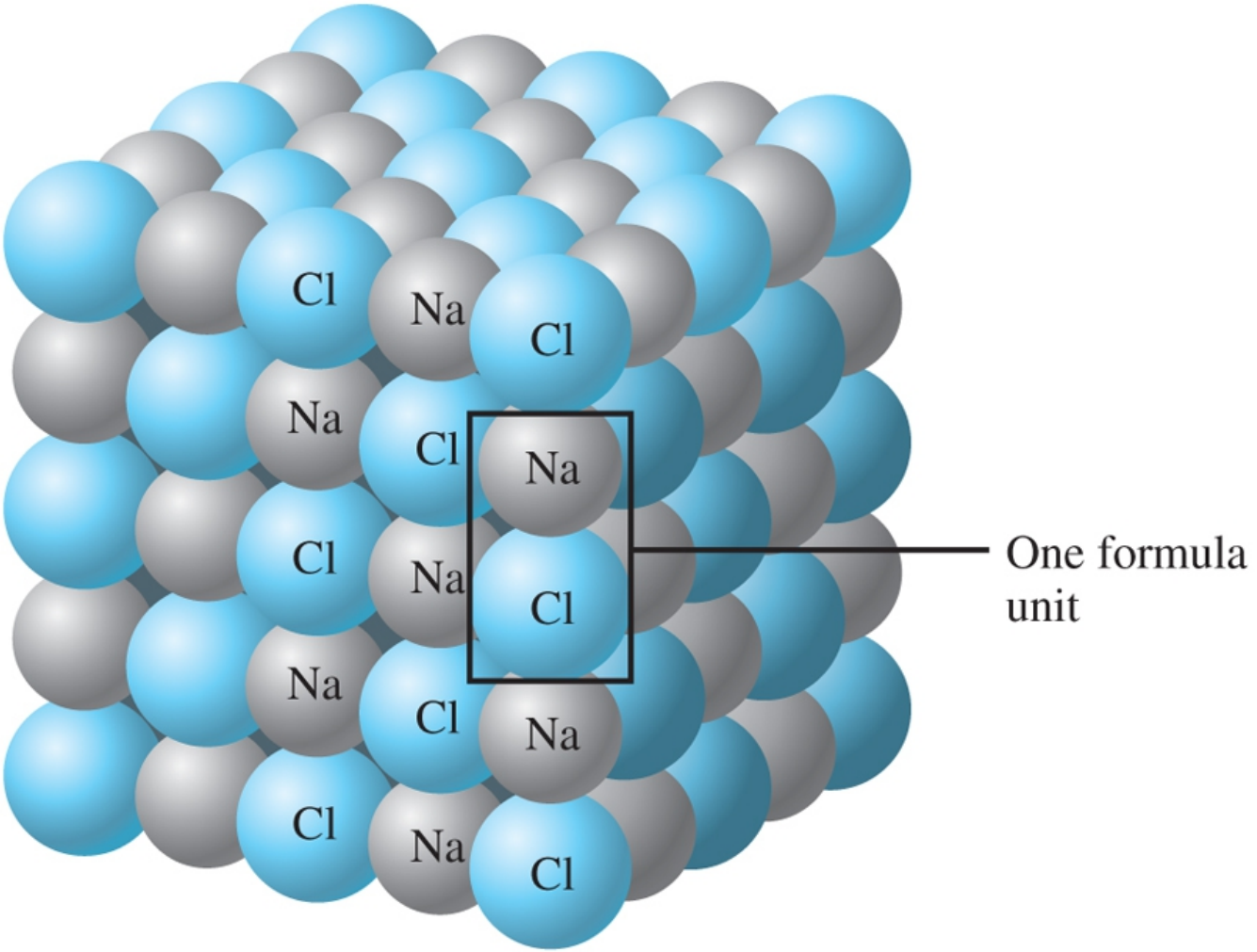
- Have fixed ratios of positive to negative ions

- Overall electrically neutral

- Solid structure is a stacked array of ions

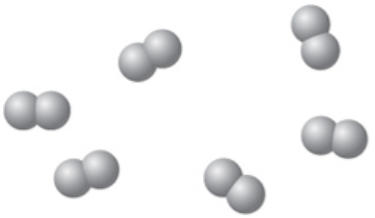


(a) A molecule of the molecular compound methane (CH_4)

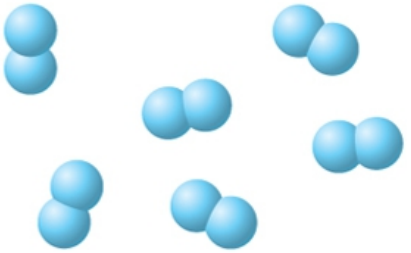


(b) A formula unit of the ionic compound sodium chloride (NaCl)

Elements

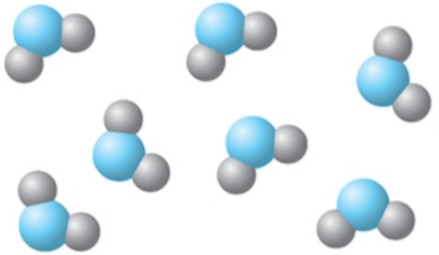


Hydrogen (H_2) molecules

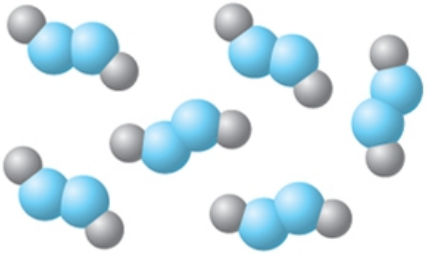


Oxygen (O_2) molecules

Compounds

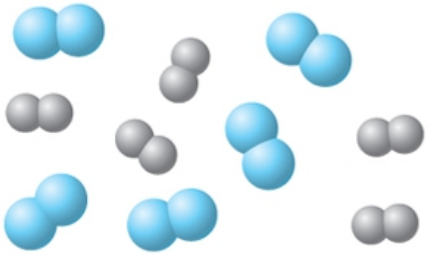


Water (H_2O) molecules

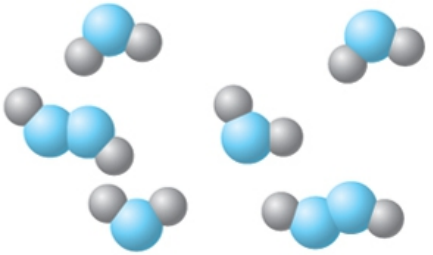


Hydrogen peroxide (H_2O_2) molecules

Mixtures



Mixture of hydrogen (H_2) and oxygen (O_2), a mixture of elements



Mixture of hydrogen peroxide (H_2O_2) and water (H_2O), a mixture of compounds

Chemical Formulas

- Shows how many of each atom are in a compound:
  - For molecules, the formula shows the exact number in a molecule, and sometimes give structural information
  - For ionic compounds, the formula shows the lowest whole number ratios of one ion to the others in the compound
  - Parenthesis – groups atoms, gives structural information
  - Subscripts – show how many of each element/group are in the formula

$H_2CO_3 = 2\ H + 1\ C + 3\ O$

$C_2H_3COOH = 3\ C + 4\ H + 2\ O$

$Ca(OH)_2 = 1\ Ca + 2\ O + 2\ H$

$Al_2(SO_4)_3 = 2\ Al + 3\ S + 12\ O$