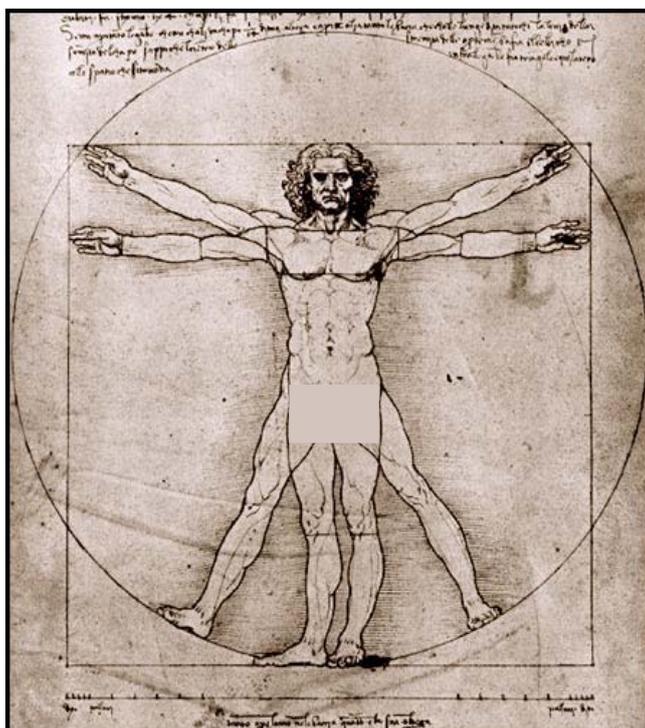




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Chem Lectures

Elements, Compounds and Mixtures



The Vitruvian Man, a drawing by Leonardo Da Vinci, shows the intricacies and geometry of the human body. Many say that Da Vinci was a man ahead of his time, by almost 100 years. However, little did he know that the human body is actually made up of many different elements, compounds and mixtures. Today, we know that the average adult human body is made up of around 60 different elements, with oxygen, carbon, hydrogen and nitrogen contributing the bulk of the elements. We also know that the human body is about 65% water.

What other elements do you think can be found in the human body?

What other compounds do you think can be found in the human body?

What mixtures do you think can be found in the human body?

Learning Outcomes

1. Define an element, a compound and a mixture.
2. Describe ways of classifying elements.
3. Give the names and symbols of common elements.
4. Describe the kinds of particles in elements and compounds.
5. Describe the differences between elements, compounds and mixtures.
6. Interpret chemical equations with state symbols and balance them appropriately.

1. What are Elements?

An element is a substance that

- Chemical methods used can be heat, electricity, light, etc.
- If a substance breaks down, it is known as a compound, e.g.,

sodium chloride → sodium + chlorine

- There are 118 elements discovered to date, and 112 officially named.

The Periodic Table of the Elements

Group																			
I	II													III	IV	V	VI	VII	0
																		4.0 He helium 2	
6.9 Li lithium 3	9.0 Be beryllium 4	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> Key relative atomic mass atomic symbol name atomic number </div>												10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36		
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	– Tc technetium 43	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54		
133 Cs caesium 55	137 Ba barium 56	139 La lanthanum 57	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	195 Pt platinum 78	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	– Po polonium 84	– At astatine 85	– Rn radon 86		
– Fr francium 87	– Ra radium 88	– Ac actinium 89	– Rf rutherfordium 104	– Db dubnium 105	– Sg seaborgium 106	– Bh bohrium 107	– Hs hassium 108	– Mt meitnerium 109	– Unu ununium 110	– Uuu ununium 111	– Uub ununium 112	– Uuq ununquadium 114	– Uuh ununhexium 116	– Uuo ununoctium 118	–	–	–		

lanthanides *	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	– Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
actinides *	– Th thorium 90	– Pa protactinium 91	– U uranium 92	– Np neptunium 93	– Pu plutonium 94	– Am americium 95	– Cm curium 96	– Bk berkelium 97	– Cf californium 98	– Es einsteinium 99	– Fm fermium 100	– Md mendelevium 101	– No nobelium 102	– Lw lawrencium 103

Figure 1.1 Periodic Table of elements

- Each element has a name and a chemical symbol, e.g., carbon, C; hydrogen, H.
- Elements can be classified by various ways:
 - State:** Classified by their physical state at room temperature and pressure (r.t.p.), e.g., of the 92 naturally occurring elements, 11 are gases, two are liquids, the remaining 79 are solids.
 - Metals, metalloids, non-metals:** Depending on how well they conduct electricity, e.g., sodium and lead are metals, silicon is a metalloid, while carbon and sulfur are non-metals.
 - By atomic number in the Periodic Table:** Arranged according to their atomic (proton) number. Trends in physical and chemical properties are observed in this arrangement.

2. What are Elements Made of?

- **An atom is the**
- Atoms are extremely small, on the scale of 10s to 100s of picometres (pm), 10^{-12} m.
- An element, such as carbon, comprises many carbon atoms packed closely together.

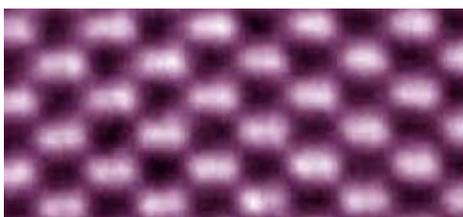


Figure 2.1 Atoms of carbon in diamond, an allotrope of carbon, taken with an electron microscope

- **A molecule is a group of**
The atoms in the molecule need not be the same type of atoms, e.g., a molecule of hydrogen, H_2 ; a molecule of water, H_2O .
- Most non-metals are made up of molecules, e.g., chlorine gas comprises chlorine molecules, with each molecule made up of 2 atoms of chlorine.

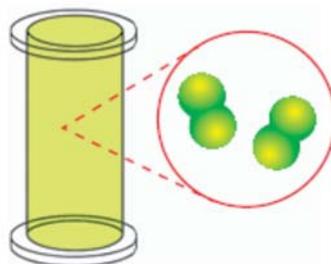


Figure 2.2 Chlorine gas is made up of diatomic chlorine molecules

- The chemical formula of a molecule shows the number and kinds of atoms contained in it, e.g.,

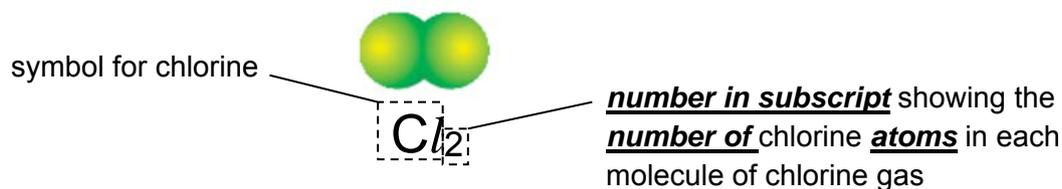


Figure 2.3 A molecule of chlorine

- Molecules of non-metal elements can be made up of different number of atoms, e.g.,

Monatomic	Diatomic molecule	Triatomic molecule	Polyatomic molecule
			
helium (He) neon (Ne) argon (Ar)	oxygen (O ₂) hydrogen (H ₂) chlorine (Cl ₂)	Ozone (O ₃)	Phosphorus (P ₄)

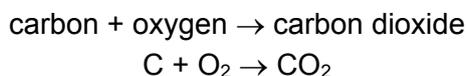
Checkpoint 1

Using hydrogen gas as an example, explain how a molecule differs from an atom.

3. What are Compounds?

- **A compound is a substance containing**

- Most of the substances that we see around us are compounds, e.g., water, H₂O; common salt or sodium chloride, NaCl.
- Elements can combine in a chemical reaction to form compounds, e.g.,



- This is a chemical change and is irreversible. The compound formed has physical and chemical properties different from that of the elements that made up the compound.
- The following rules are used in naming a compound:

General rule	Examples
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General rule	Examples
If a compound contains both metal and non-metal, the metal is usually written first in the formula.	Sodium chloride, NaCl \Rightarrow written with sodium, Na, first.
A compound with only two elements often ends in -ide	Sodium chloride, NaCl Magnesium oxide, MgO Carbon dioxide, CO ₂ Lead bromide, PbBr ₂
A compound that contains OH is named a hydroxide .	sodium hydroxide , NaOH calcium hydroxide , Ca(OH) ₂ copper(II) hydroxide , Cu(OH) ₂
A compound with an ion containing oxygen usually ends in -ate .	Calcium carbonate, CaCO ₃ Silver nitrate, AgNO ₃ Lead(II) sulfate, PbSO ₄
The number of atoms in a formula is written as a subscript; with the exception of 1.	Water, H ₂ O Copper(II) sulfate, CuSO ₄ Iron(III) nitrate, Fe(NO ₃) ₃
The roman numerals are used to denote oxidation state (more about this later).	Iron(II) hydroxide, Fe(OH) ₂ Iron(III) hydroxide, Fe(OH) ₃
For covalent molecules, for some compounds, we usually name the entire compound by counting the number of atoms.	Carbon dioxide, CO ₂ Carbon monoxide, CO
For others, we use their common names.	Water, H ₂ O Ammonia, NH ₃

4. What do Compounds Comprise?

- Compounds are made up of molecules and/or ions.

(1) Molecules, e.g., for water,

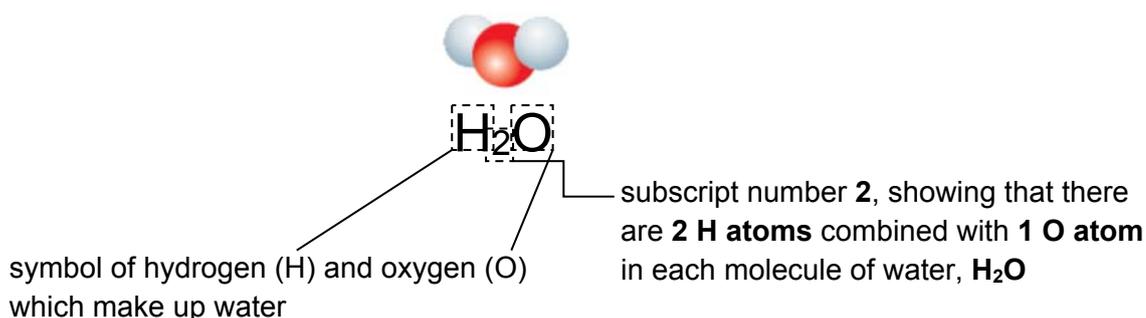


Figure 4.1 A molecule of water

(2) Ions

- **An atom or a group of atoms that has an ion.** e.g., sodium chloride is made up of two kinds of ions,
 - sodium ions, bearing a positive charge, +, (**cation**).

- chloride ions, bearing a negative charge, $-$, (**anion**).
- Compounds made up of ions are known as ionic compounds, e.g., sodium chloride, copper(II) sulfate, iron(III) hydroxide, are ionic compounds.

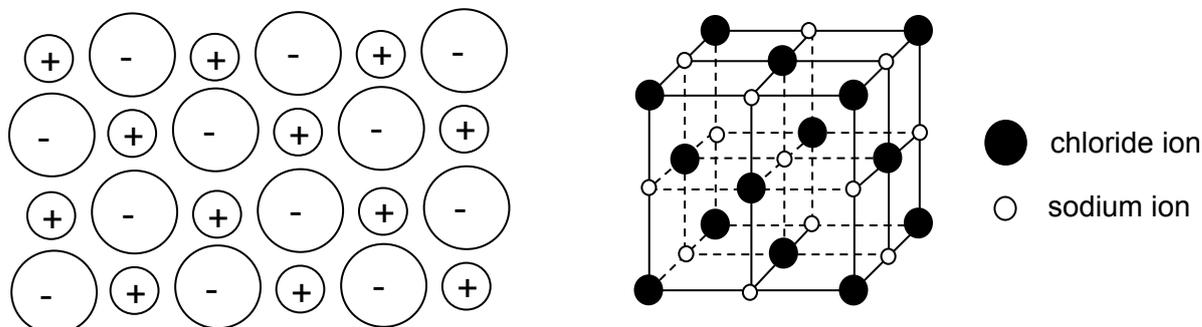


Fig. 4.2 Sodium chloride comprises sodium cations and chloride anions

Common Misconception

We can say that carbon dioxide is made up of CO_2 molecules. However, we cannot say that sodium chloride is made up of NaCl molecules. This is because, NaCl is made up of ions. Molecules do not bear a charge, i.e., they are electrically neutral.

Hence, we will term the following as ions, not molecules, even though they comprise more than two elements chemically combined together, because they bear an electrical charge: CO_3^{2-} , carbonate ion; SO_4^{2-} , sulfate ion; NH_4^+ , ammonium ion.

5. What are Mixtures?

- ***A mixture consists of***

e.g., air, milk, alloys such as stainless steel and brass.

- A mixture can be represented with a particle model as follows:

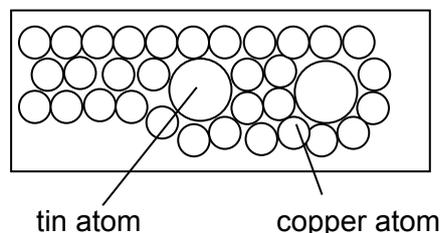


Figure 5.1 Bronze, an alloy, is a mixture of copper and tin

- **A compound and a mixture are not the same:**

	Compound	Mixture
Composition	_____ composition by mass, e.g. water is H ₂ O, not HO ₂ .	_____ composition by mass, e.g., a mixture of Ribena can contain less or more water.
Melting and boiling points	_____ melting and boiling points, e.g., water melts at 0 °C and boils at 100 °C.	_____ melting and boiling points, e.g., butter melts over a range of temperatures.
Properties	Physical and chemical properties of a compound are different from its elements, e.g., Hydrogen reacts explosively with oxygen, but water does not.	Does not usually have its own properties, but rather has properties of its components, e.g., a mixture of iron filings and water is not magnetic, only the iron filings are magnetic.
Separation	Cannot be separated into two or more substances by physical means; a chemical reaction is required to separate the elements, e.g., water cannot be separated into hydrogen and oxygen by filtering, distillation, etc. Electrolysis is required to split water into hydrogen and oxygen.	Can be easily separated into its components by physical means without a chemical reaction, e.g., a mixture of iron filings and water can be separated by filtration.

Checkpoint 2

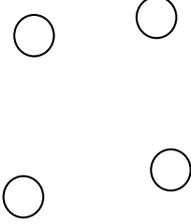
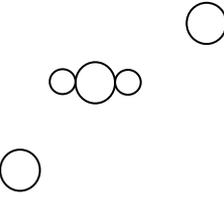
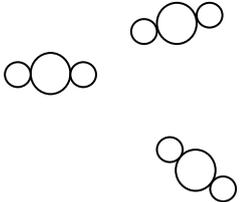
1. Objects have been made out of bronze for thousands of years. The bronze used to make three ancient Chinese bells around 500 B.C. were analysed. The results of the analysis are shown below:

Bell	% of copper by mass	% of tin by mass
1	85	15
2	83	17
3	86	14

- a) Is bronze a mixture or a compound? Explain your answer.

- b) Suggest how you could test a sample of bronze to prove your answer.

2. Identify the figures below which represents a mixture, an element, and a compound.

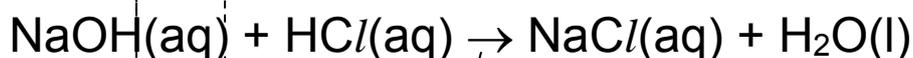
			
A	B	C	D
Mixture: Element: Compound:			

6. Communicating the Involvement of Atoms, Elements, Compounds, Molecules and Ions in Chemical Reactions

- Chemical reactions typically involve two or more different compounds at suitable conditions reacting together, e.g., solid HCl and solid NaOH will not react; aqueous HCl and aqueous NaOH will react.
- This reaction is communicated across in a universal chemical language, the chemical equation.
- A chemical equation illustrates a chemical reaction**, e.g.,

This is the chemical formula of sodium hydroxide

This is the state symbol to represent the state of sodium hydroxide, in this case, aqueous



The **reactants** are placed on the left hand side of the chemical equation

The **products** are placed on the right hand side of the chemical equation

- This chemical equation will read literally, aqueous "sodium" hydroxide reacts with aqueous hydrochloric acid to form aqueous sodium chloride and liquid water.

- Some of common state symbols used in chemical equations are:
 - aqueous (aq) [**Note:** Aqueous means dissolved in water]
 - gas (g)
 - liquid (l) [**Note:** we also use (l) to represent dilute solutions, e.g., dilute sulfuric acid, H₂SO₄(l)]
 - solid (s)
- Both sides of the chemical equation must ALWAYS be balanced**, i.e., the same number of atoms of each kind must be on the LHS and RHS, e.g.,

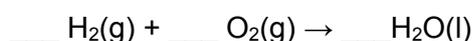
LHS	RHS	Outcome
1 Na	1 Na	balanced
1 O	1 O	balanced
2 H	2 H	balanced
1 Cl	1 Cl	balanced

Checkpoint 3

Convert the following word equations to balanced chemical formula equations with state symbols:

- a) hydrogen gas reacts with oxygen gas to form liquid water [This is a worked example.]

Step 1: Write out the chemical equation without balancing any of the atoms. Remember to include the state symbols.



Step 2: Count the number of H on both sides.

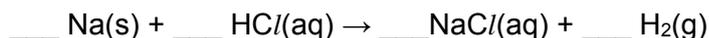
Step 3: Count the number of O on both sides.

Step 4: Recount the number of H and O on both sides.

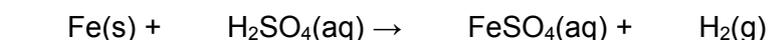
Step 5: Final balanced equation with state symbols.

Note: When writing the actual equations, there is no need to do all 5 steps one-by-one. Simply work off the equation that you write in Step 1.

- b) sodium metal reacts with dilute hydrochloric acid to form aqueous sodium chloride and hydrogen gas



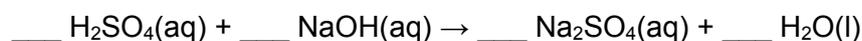
- c) iron metal reacts with dilute sulfuric acid to form aqueous iron(II) sulfate and hydrogen gas



- d) dilute hydrochloric acid reacts with solid calcium carbonate to form aqueous calcium chloride, carbon dioxide gas and liquid water



- e) dilute sulfuric acid reacts with dilute sodium hydroxide to form aqueous sodium sulfate and liquid water



- f) aqueous ammonium chloride reacts upon heating with dilute sodium hydroxide to form aqueous sodium chloride, liquid water and ammonia gas



- g) heating solid calcium carbonate results in the formation of solid calcium oxide and carbon dioxide gas

