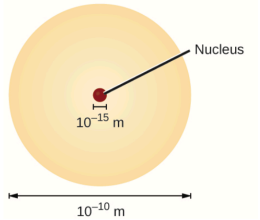
Introduction to Physical Science

Atomic Structure and Chemical Formulae

Presented by Robert Wagner

Atomic Structure

- We learned that an atom consists of a tiny nucleus surrounded by electrons
- If the nucleus were the size of a blueberry, the entire atom would be the size of a football stadium!
- New units:
  - Fundamental unit of charge: e
  - Atomic mass unit - amu



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Units

- New units make it easier to deal with the numbers for such small objects

Properties of Subatomic Particles

Name	Location	Charge (C)	Unit Charge	Mass (amu)	Mass (g)
electron	outside nucleus	-1.602×10^{-19}	1−	0.00055	0.00091×10^{-24}
proton	nucleus	1.602×10^{-19}	1+	1.00727	1.67262×10^{-24}
neutron	nucleus	0	0	1.00866	1.67493×10^{-24}

Table 2.2

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Atomic Number

- The atomic number (Z) defines the atom. It is the number of protons in the nucleus of the atom
- The mass number (A) is the total number of protons and neutrons in the atom
- The atomic charge of an atom is the number of protons minus the number of electrons.
  - If they are not equal, the atom is electrically charged and is called an ion
  - Anion - negatively charged
  - Cation - positively charged

Example

- Iodine atoms added to salt are anions each with a -1 charge and a mass number of 127. How many protons, neutrons and electrons would be in one of these iodine anions?

Atom - Iodine ; anion ; A = 127

For iodine, we can look up the atomic number: Z = 53 = number of protons

A = 127 and Z = 53 so, the number of neutrons is 127-53 = 74

If it were neutral, the number of protons would be the same as the number of electrons but we have a -1 charge

53 + 1 = 54 electrons.

So, 53 protons, 74 neutrons and 54 electrons

Chemical Symbols

- Chemical symbol - 1-3 letter abbreviation for an element
- Only the first letter is capitalized
- Examples

Some Common Elements and Their Symbols

Element	Symbol	Element	Symbol
aluminum	Al	iron	Fe (from *ferrum*)
bromine	Br	lead	Pb (from *plumbum*)
calcium	Ca	magnesium	Mg
carbon	C	mercury	Hg (from *hydrargyrum*)
chlorine	Cl	nitrogen	N
chromium	Cr	oxygen	O
cobalt	Co	potassium	K (from *kalium*)
copper	Cu (from *cuprum*)	silicon	Si
fluorine	F	silver	Ag (from *argentum*)
gold	Au (from *aurum*)	sodium	Na (from *natrium*)
helium	He	sulfur	S
hydrogen	H	tin	Sn (from *stannum*)
iodine	I	zinc	Zn

Table 2.3

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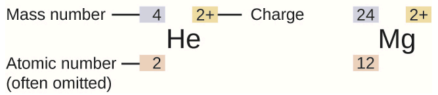
Isotopes

- Isotopes have different numbers of neutrons in the nucleus
- Magnesium has isotopes with mass numbers of 24, 25 and 26
- These can be written as:
  - ^{24}Mg, ^{25}Mg, ^{26}Mg
  - Magnesium-24 or Mg-24, etc.



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Atomic Mass

- May not be whole numbers because different isotopes exist
- Average mass = sum of (fractional abundance x mass of isotope) for each isotope
- Example: Boron

$$^{10}B : 19.9\,\%\ of\ atoms\ ;\ 10.0129\ amu$$

$$^{11}B : 80.1\,\%\ of\ atoms\ ;\ 11.0093\ amu$$

$$Avg\ Mass = (0.199x10.0129\ amu) + (0.801x11.0093\ amu)$$

$$Avg\ Mass = 1.99\ amu + 8.82\ amu$$

$$Avg\ Mass = 10.81\ amu$$

Chemical Formulae

- Molecular Formula - uses chemical symbols and numbers
- Structural Formula - Shows how atoms are connected
- Ball and Stick and Space-filling models - shows the geometric arrangement of the atoms

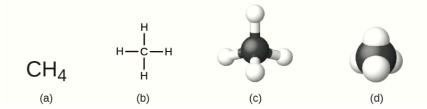

Figure 2.16 A methane molecule can be represented as (a) a molecular formula, (b) a structural formula, (c) a ball-and-stick model, and (d) a space-filling model. Carbon and hydrogen atoms are represented by black and white spheres, respectively.

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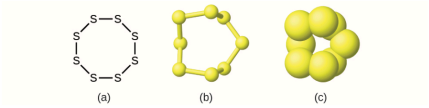

Figure 2.17 A molecule of sulfur is composed of eight sulfur atoms and is therefore written as S_8. It can be represented as (a) a structural formula, (b) a ball-and-stick model, and (c) a space-filling model. Sulfur atoms are represented by yellow spheres.

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Molecules

- The subscript and the number in front of the symbol represent two different things
  - Subscript - number of atoms bonded together
  - Number in front - How many of those molecules/atoms
- Example - Hydrogen

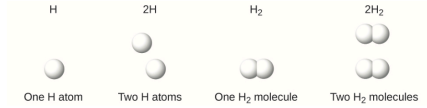

Figure 2.18 The symbols H, 2H, H_2, and $2H_2$ represent very different entities.

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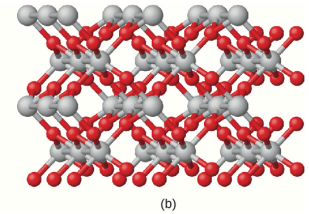
Empirical Formulae

- An empirical formula includes information on the types of atoms present and the simplest whole-number ratio of the number of atoms in the compound.
- Example:
- Differs from a molecular formula which gives the actual numbers of each atom in a molecule
- Example: Acetic Acid:



(b)

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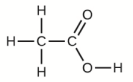
Empirical Formulae



(b)

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- Example:
- Differs from a molecular formula which gives the actual numbers of each atom in a molecule
- Example: Acetic Acid:

$Molecular: C_2H_4O_2$

$Empirical: CH_2O$

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Example

- Molecules of glucose contain 6 carbon atoms, 12 hydrogen atoms and 6 oxygen atoms. What are the molecular and empirical formulae for glucose.

$6\,C\,;\ 12H\,;\ 6O$

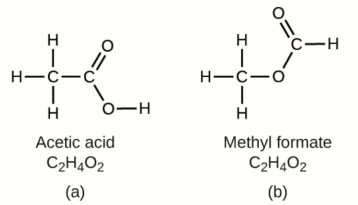
$Molecular: C_6H_{12}O_6$

Ratio of C:H:O = 1:2:1

$Empirical: CH_2O$

Isomers

- Isomers have the same chemical formulae but different chemical structures
- Example:



Summary

- Atoms can be described by the atomic number (Z), mass number (A) and atomic charge
- Molecular formulae are used to identify specific elements and differentiate between isotopes. A structural formula will show how the atoms are bonded together
- An empirical formula differs from a molecular formula in that it reduces to the simplest whole-number ratio