CHEM 103
Atoms

Lecture Notes
January 31, 2006
Prof. Sevian

Agenda

- A few announcements
  - Discussion and lab both start this week
  - Links to online skill drills are in the Miscellaneous section in the course website
- More calculations skills you need
  - Scientific notation
- What are atoms? How do we know? Why should you care?
- How do atoms make compounds? What kinds of compounds exist? How do we name them?
Concerning lab exemptions

- Today is the deadline for requesting lab exemptions
- To request a lab exemption, you must EMAIL me a request so that your request is documented in writing (for your own protection)
- I will email you an answer to whether you have a lab exemption
- Until you receive an answer, you must attend lab, in case you do not receive a lab exemption

Some Measurements and Conversions You Need to Know

*Two types of conversions*

- Proportional
  - Time
  - Length or distance
  - Volume
  - Mass
- Equations
  - Temperature
Time Conversions

\[
2.5 \text{ hours} \times \frac{? \text{ something}}{? \text{ hours}} \times \frac{? \text{ seconds}}{? \text{ something}} = ? \text{ seconds}
\]

\[
2.5 \text{ hours} \times \frac{60 \text{ minutes}}{1 \text{ hour}} \times \frac{60 \text{ seconds}}{1 \text{ minute}} = 9000 \text{ seconds}
\]

How can you write 9000 so it’s clear it has 2 sig figs?

HOLD THAT THOUGHT...

Metric Prefix Meanings for Conversions

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centi (c)</td>
<td>1/100th of</td>
<td>1 cm = 0.01 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 cm = 1 m</td>
</tr>
<tr>
<td>Milli (m)</td>
<td>1/1000th of</td>
<td>1 mL = 0.001 L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 mL = 1 L</td>
</tr>
<tr>
<td>Kilo (k)</td>
<td>1000 of</td>
<td>1 kg = 1000 g</td>
</tr>
<tr>
<td>Micro (μ)</td>
<td>10^{-6} of</td>
<td>1 μmol = 10^{-6} mol</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,000,000 μmol = 1 mol</td>
</tr>
<tr>
<td>Nano (n)</td>
<td>10^{-9} of</td>
<td>1 nm = 10^{-9} m</td>
</tr>
</tbody>
</table>
Conversions Using Metric System

1) How many moles are in 12.2 mmol?

\[
12.2 \text{ mmol} \times \frac{1 \text{ mol}}{1000 \text{ mmol}} = 0.0122 \text{ mol}
\]

2) Red light has a wavelength of 630 nm. How many meters is that?

\[
630 \text{ nm} \times \frac{10^{-9} \text{ m}}{1 \text{ nm}} = 6.3 \times 10^{-7} \text{ m}
\]

Volume Conversions

Important volume conversion to remember: \(1 \text{ mL} = 1 \text{ cm}^3\)

A can of soda is marked as having 258 cc of soda in it. How many liters is this?

\[
258 \text{ cm}^3 \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.258 \text{ L}
\]
Temperature Scales

- **Boiling point of water**: 212 °F = 100 °C = 373 K
- **Human body temperature**: 98.6 °F = 37 °C = 310 K
- **Freezing point of water**: 32 °F = 0 °C = 273 K

### Temperature Conversions Require Equations

**Celsius (°C) ↔ Kelvin (K)**

You need to memorize this conversion!!!

\[
K = °C + 273.15 \quad \text{or} \quad °C = K - 273.15
\]

Example: A gas has a temperature of 25.8 °C. What is the temperature in Kelvin?

\[
K = °C + 273.15
\]

\[
= 25.8 + 273.15 = 298.95 \text{ K}
\]

Rounds to 299.0 K

**Sig figs:**

One place beyond decimal pt
Really Big Numbers

In a 22.4 liter sample of air at standard conditions, there are approximately this many particles present:

\[602,204,531,000,000,000,000,000,000\]

\[= 6.02204531 \times 10^{23} \text{ particles}\]

Really Small Numbers

A single snowflake has a mass of approximately

\[0.000\ 0030\ \text{kg}\]

\[= 3.0 \times 10^{-6} \text{ kg}\]
Calculations Using Scientific Notation

- A typical snowflake has $100 = 10^2$ ice crystals
- A single ice crystal has $10^{18}$ water molecules
- A water molecule has a mass of $3.0 \times 10^{-26}$ kg
- Therefore, a typical snowflake has a mass of approximately

\[
10^2 \text{ crystals} \times \frac{10^{18} \text{ water molecules}}{1 \text{ crystal}} \times \frac{3.0 \times 10^{-26} \text{ kg}}{1 \text{ water molecule}} = 3.0 \times 10^{-6} \text{ kg}
\]


Scientific Notation

- A nice way to represent big and small numbers
- Makes it easy to indicate significant figures
  9000 written with two sig figs is $9.0 \times 10^3$
- Makes it easy to estimate answers
  $(3.0 \times 10^8) \times (2.0 \times 10^{-6}) = 6.0 \times 10^2$
- Scientific notation and your calculator → try the practice problems in the Assignments section on the course website to make sure you are proficient at using scientific notation in your own calculator
Brief Review

Homogeneous mixture
or
Heterogeneous mixture
or
Element
or
Compound
?

What is an Atom?

B.C.E. – Democritus: an atom is the smallest particle of matter

1800’s – Electrons exist and they have some properties
(negative charge, very small mass)

Late 1800’s-Mid 1900’s – Protons and neutrons exist and they have some properties (protons are +, neutrons are neutral, have nearly same mass which is > electron mass)

How is the atom organized?

What is the nucleus?
What does an atom look like?

Model 1
Thomson, 1898
has + and - charges

Model 2
Rutherford, 1910
Nucleus (+) is very small,
atom is mostly empty space

Nucleus contains
most of mass and
all of + charge.
Size is $10^{-12}$ cm.

Electrons
occupy
most of
atom’s
space
(though
tiny) $10^{-8}$

Note: not drawn to scale!

More about Rutherford’s Experiments

“...fired a 15-inch shell into a
piece of tissue paper and it
came back and hit you.”

– Ernest Rutherford
What does an atom look like?

Model 3

shell #4 (can hold up to 18 electrons)
shell #3 (can hold up to 8 electrons)
shell #2 (can hold up to 8 electrons)
shell #1 (can hold up to 2 electrons)
nucleus

Bohr, 1912

Model explains the hydrogen spectrum (stay tuned until chapter 6…)

Note: not drawn to scale!

What does an atom look like?

Model 4

Schrodinger, Heisenberg, Bohr, de Broglie and some others, 1912-1924

Figure 7.15 - Atomic orbitals. Bonding surface diagrams for electron densities of 2s, 2p, 3s, 3p, and 3d orbitals for a hydrogen atom. For the p orbitals, the subscripts letter on the orbital notation (x, y, z) indicates the direction along which the orbital lies. The plane passing through the nucleus (perpendicular to this axis) is called a node surface (n = 1). The d orbitals all have two node surfaces (n = 2).© C 2003. Reprinted with permission of Brooks/Cole, a division of Thomson Learning; www.brookscole.com. Fax 800-730-2215.

Quantum Mechanical Model = current working model (stay tuned until chapter 7 for more information…)

### What’s in an Atom?

<table>
<thead>
<tr>
<th>Location</th>
<th>Charge</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>+</td>
<td>~1 a.m.u.</td>
</tr>
<tr>
<td>Neutron</td>
<td>0</td>
<td>~1 a.m.u.</td>
</tr>
<tr>
<td>Electron</td>
<td>-</td>
<td>(\frac{1}{1836}) th of an a.m.u.</td>
</tr>
</tbody>
</table>

### The Actual Numbers

<table>
<thead>
<tr>
<th>Charge</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton: (+1.602 \times 10^{-19}) C</td>
<td>1.007276 a.m.u.</td>
</tr>
<tr>
<td>Neutron: 0</td>
<td>1.008665 a.m.u.</td>
</tr>
<tr>
<td>Electron: (-1.602 \times 10^{-19}) C</td>
<td>0.00054858 a.m.u.</td>
</tr>
</tbody>
</table>

Atomic mass units

1 a.m.u. = \(1.661 \times 10^{-24}\) grams
Important Implications

1. For an atom to be neutral, it must have equal quantities of protons (+) and electrons (-).
2. Different quantities of neutrons do not affect the total charge of an atom. It (apparently) doesn’t matter how many neutrons are in an atom.
3. Most of the mass of an atom is in the nucleus (protons and neutrons). Can estimate an atom’s mass by counting protons + neutrons.

How Can the Nucleus Vary?

Three different isotopes of hydrogen atoms
(Note: Bohr model is incorrect, but very useful)

<table>
<thead>
<tr>
<th>Same</th>
<th>All have 1 electron</th>
<th>All have 1 proton</th>
<th>All neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different</td>
<td>No neutrons</td>
<td>1 neutron</td>
<td>2 neutrons</td>
</tr>
<tr>
<td>Symbol</td>
<td>$^1_1\text{H}$</td>
<td>$^2_1\text{H}$</td>
<td>$^3_1\text{H}$</td>
</tr>
</tbody>
</table>
How Can the Nucleus Vary?

Three different isotopes of carbon atoms
(Note: Bohr model is incorrect, but very useful)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>6 C¹²</th>
<th>6 C¹³</th>
<th>6 C¹⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>All have 6 electrons</td>
<td>All have 6 protons</td>
<td>All neutral</td>
</tr>
<tr>
<td>Different</td>
<td>6 neutrons</td>
<td>7 neutrons</td>
<td>8 neutrons</td>
</tr>
</tbody>
</table>

What Information does the Symbol Contain?

Where is each piece of information contained?
- How many protons?
- Why is the quantity of protons called the atomic number?
- How many neutrons?
- How many total particles in the nucleus? Why is this called the mass number?
- What element is it?

Difference = Neutrons

Mass number

Atomic number
Catching up on some vocabulary

How would you define these words now?

- Isotope
- Nucleus
- Neutral
- Mass number
- Atomic number

Think-Pair-Share

Fill in the missing information

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Protons</th>
<th>Neutrons</th>
<th>Mass Number</th>
<th>Electrons (in neutral atom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{11}_{5}$B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>37</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What does % mean in chemistry?

\[
% = \frac{\text{part}}{\text{whole}} \times 100
\]

Example: How would you figure out what % of students in the room are between the ages of 20-29?

Isotopes and Natural Abundances

The mass of a typical sample of an element is a weighted average of the masses of the isotopes.

<table>
<thead>
<tr>
<th>Isotopes of magnesium</th>
<th>Natural Abundance</th>
<th>Mass of Isotope (amu)</th>
<th>This is the atomic weight on the periodic table</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 p⁺</td>
<td>78.99%</td>
<td>23.9850</td>
<td></td>
</tr>
<tr>
<td>12 n°</td>
<td>×</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>13 n°</td>
<td>10.00%</td>
<td>24.9858</td>
<td></td>
</tr>
<tr>
<td>14 n°</td>
<td>×</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>25.9826</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.95 + 2.499 + 2.861</td>
<td>= 24.31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reading the Periodic Table

**Mg**

Atomic number: 12
Symbol: Mg
Atomic weight: 24.31

Regions of the Periodic Table

- **Transition metals**
- **Lanthanides and actinides**

---

Lanthanides and actinides: Elements 57 to 71 and 89 to 92, respectively.
Organization of the Periodic Table

Terminology we will use all year

- **Period** = row across
- **Group** = column down

Several common groups

- **Group 1A**: Alkali metals
- **Group 2A**: Alkaline earth metals
- **Group 7A**: Halogens
- **Group 8A**: Noble gases
- **Groups B**: Transition metals

- Early chemists (Mendeleev, Moseley) organized the Periodic Table according to properties of elements
- There are reasons why the Periodic Table is organized the way it is (stay tuned until chapters 6 and 7)

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Pinpointing an Element