Learning Guide for Lecture 1B – The World is Made of Legos
Chem 1010

Review

Let's begin by reviewing what we learned about chemistry:

What is chemistry?

What are some examples of things that we can study with chemistry?

Introduction

In today's lecture, we will begin our study of matter, the stuff the universe is made of.

I. Atoms, Elements, Compounds, and Chemical Reactions

> First, we'll look at four fundamental ideas: atoms, elements, compounds, and chemical reactions.

II. How Small Are Atoms?

> Second, we will talk about how small atoms are, and give some examples that help to illustrate this. We'll also look at some images of actual atoms, and talk about how to count them.

III. What are Atoms Made Of?

> Finally, we'll introduce the elementary particles, which is what atoms are made of. We'll discuss how they are arranged in an atom, and how they determine an atom's charge and mass.

I. Atoms, Elements, Compounds, and Chemical Reactions

If you could look at matter really close up, what would it look like?

Atoms

The first thing you probably noticed is that matter is made of lots of little round balls.

These little balls are called:

All of the matter in the universe is made of atoms.

examples:

It's a little like looking at a sand dune...

It's also like a picture stored in a computer...

It's also like building things out of Legos...

Have you have heard of the idea that all matter is made of atoms before?

But here's the odd thing – nothing in our ordinary experience tells us this.

sand dunes:

digital images:

Lego structures:

atoms:

Where does the word “atom” come from?

The idea of atoms is actually pretty old – it was suggested by some Greek philosophers, _____ and _____, around 400 BC, and also appeared in _____ and _____ philosophy.

Democritus coined the term “atomos”, which means:

The philosophers had some good arguments for their ideas, but no actual evidence.

When was the first atomic theory published?

The idea of atoms didn't really catch on until _____ when _____ published the first modern atomic theory with experimental evidence to back up his claims.

Dalton was a school teacher in England who taught himself chemistry in his spare time.

Rather than reading a textbook, he waded through pages and pages of experiments performed by chemists throughout Great Britain and Europe.

By reading and thinking about these experiments, he realized that the results could only be explained if matter were made of tiny, separate particles.

This idea answered many questions that scientists had, and made it possible for our understanding of matter to really take off.

How long did it take until the idea of atoms was commonly accepted?

Even after Dalton published his atomic theory, there were some doubts among scientists about the actual existence of atoms.

This lasted until around 1900, when we began to unravel what atoms themselves are made of.

Now the evidence is so overwhelming that we no longer refer to the idea of atoms as a theory.

Elements

Another thing you probably noticed is that the little round balls that make up matter are not all alike – they are different colors and sizes.

Different kinds of atoms are called:

Do you think atoms are actually different colors?

Then how are atoms different from each other?

What are some examples of elements?

How many elements are there?

total number of known elements:

elements that have been found in nature:

elements that have been made artificially:

Compounds

You may also noticed that some of the atoms are stuck together in groups.

Atoms have the ability to connect to each other through:

For example, when only _____ atoms are present, they hook up to form pairs. These are called:

_____ and _____ atoms do the same thing.

_____ atoms, however, do not. They remain as individual atoms lined up in rows unless some other element is present.

When two or more atoms of different elements are joined together in a specific ratio, this is called a:

water:

How is water different from oxygen and hydrogen?

When atoms are combined in compounds, their properties are different from when they were separate.

What if the ratio were different?

2 atoms of hydrogen
1 atom of oxygen

2 atoms of hydrogen
2 atoms of oxygen

Do you think there could be a compound with 2 hydrogen atoms and 1.5 oxygen atoms?

table salt:

How are water and table salt different?

<u>Chemical Reactions</u>

Since the images of atoms are not in motion, you can't see from the pictures what kinds of things they can do.

Here is an example of a chemical reaction. What's happening?

A chemical reaction =

What would this reaction look like?

Here is another example. What is happening here?

Putting it all together

So far we've talked about 4 key terms:

atoms: the building blocks of matter
elements: different types of atoms
compounds: atoms joined together
chemical reactions: rearranging of connections between atoms

To review the ideas of atoms, elements, compounds, and chemical reactions, let's return to the comparison with Legos.

If an atom were a lego piece...

what would be the elements?

what would be the compounds?

what would a chemical reaction be?

Consider the following printed text. What would be the best comparison to...

an atom:

the elements:

a compound:

a chemical reaction:

II. How small are atoms?

Examples

Previously we mentioned that atoms are way too small to see, even with a microscope. So how small are they, really?

Here are some examples to help you get an idea of how small atoms really are.

1. One of the largest atoms is a uranium atom.

diameter = 350 picometers = 3.5×10^{-10} = 0.00000000035 m

How many uranium atoms would fit in a millimeter?

2. What is the smallest thing you can see?

The limit of human vision is about 200 microns, or 0.2 mm.
The largest grains of pollen are about the size.

Diamond is a substance made of pure carbon atoms.

diameter of a carbon atom = 140 picometers

If you had a diamond the same size as this grain of pollen, how many carbon atoms would be in it?

3. Before 1982, pennies were made of pure copper.

diameter of a copper atom = 270 picometers

If you turned all of the copper atoms in the penny into grains of sand, how much area would it cover?

29,377,400,000,000,000,000,000 copper atoms in a penny

Would that many grains of sand cover the floor of this room?

Would it fill this entire room?

Would it cover the Dixie State College main campus?
100 acres = 0.156 square miles = 0.405 km^2

Would it cover St. George?
65 square miles = 168 km^2

Would it cover the state of Utah?
84,899 square miles = 219,887 km^2
How deep?

Would it cover the state of California?
163,696 square miles = 423,970 km^2
How deep?

Would it cover the United States?
3,794,101 square miles = 9,826,675 km^2
How deep?

Could it cover the land surface of the earth?
149,000,000 km^2
How deep?

4. There is some gold dissolved in sea water.

A single drop of water contains 6,022,000 atoms of gold.

It is estimated that the world's oceans hold about 30,000 tons of gold (worth about $1.3 trillion).

How much ocean water would you need to get $1 worth of gold?

5.If you blew up an atom to the size of an apple, how big would an apple made of those atoms be?

An atom is to an apple as an apple is to:

Which of these examples do you like best?

Images of atoms

If atoms are so small that we can't see them with a microscope, is it still possible to get images of them?

Yes – using special instruments called scanning tunneling microscopes and atomic force microscopes.

Instead of taking a picture with light, it shows us the shape of the atoms on a surface, rather like making a pencil rubbing.

We can even manipulate single atoms to create shapes on a surface.

Moles

Since atoms are so small, how can we count them or know how many there are?

An example of this that you might be more familiar with is a dozen.

examples:

Every time you say "a dozen" you mean ___ of whatever it is.

With atoms, instead of a dozen, we use a mole.

examples:

How many atoms do you think are in a mole?

$6.022 \times 10^{23} = 6{,}022{,}000{,}000{,}000{,}00{,}000{,}000{,}000$

This is also called:

So when you say "a mole" of something you mean_____ of that thing.

How did they pick this number?

If you had a balloon filled with one mole of hydrogen, and a balloon filled with one mole of oxygen, what would be the same about each? What would be different?

III. What are atoms made of?

Elementary particles

About 100 years after Dalton published his atomic theory, scientists discovered evidence that atoms are made up of even smaller particles.

name	symbol	charge	mass*

*1 Dalton = 1.66×10^{-27} kg (0.00000000000000000000000000166 kg)

How do the sizes of the protons, neutrons, and electrons compare?

If a proton or neutron were the size of a _____, an electron would be the size of a _____.

How do the charges on the proton and electron compare?

How atoms are put together

Draw a simple picture of how the elementary particles are arranged in the atom:

If two atoms interact with each other to form a chemical bond, which elementary particles will be involved?

What are some examples of this?

How big is the nucleus compared to the rest of the atom?

If you expanded an atom to the size of a _____, the nucleus would be the size of a _____ in the middle of the room.

Properties of an atom

What makes a copper atom a copper atom, and not a gold atom?

type of atom	number of protons
hydrogen	
carbon	
oxygen	
sodium	
chlorine	
copper	
gold	
uranium	

The number of protons in an atom is called the _____.

A typical carbon atom has:

____ protons
____ neutrons
____ electrons

This gives it a mass of:

and a charge of:

What would happen if you removed a neutron from this atom?

____ protons
____ neutrons
____ electrons

Is it still a carbon atom?

Does it still have a mass of 12 Da?

Does it still have a charge of 0?

Two atoms that are the same element but have different masses are called:

What would happen if you added an electron from the original carbon atom?

____ protons
____ neutrons
____ electrons

Is it still a carbon atom?

Does it still have a mass of 12 Da?

Does it still have a charge of 0?

Any atom with a charge is called:

What would happen if you added a proton to the original carbon atom?

____ protons
____ neutrons
____ electrons

Is it still a carbon atom?

Does it still have a mass of 12 Da?

Does it still have a charge of 0?

If you change the number of protons, you change:

Summing up:

Which elementary particle gives the atom its identity?

Which elementary particles are involved in the mass?

Which elementary particles are involved in the charge?

Which of these is easiest to change?