



Biochemistry Literacy for Kids

Biochem 2.0 Unit 1: PANORAMA

Course Scope and Lesson 1 Workbook

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Course Contents

The 10 lessons are divided into smaller sections with the following topics.

1. Molecular Model Building

- A. Hydrocarbons
- B. Bonds and Lone Pairs
- C. Bonding Rules

2. Planetary Atmosphericics

- A. Terrestrial Planets
- B. Gas Giants and Ice Giants
- C. The Elements of Life

3. Molecular Drawing

- A. Small Molecules
- B. NSAID Medicines

4. Hemoglobin

- A. The Size of Cells
- B. The Heme and Oxygen Binding
- C. Carbon Dioxide Binding
- D. Gas Transport in the Body

5. Aromas

- A. Odors and Odorless Molecules
- B. Skeletal Structures
- C. Functional Groups
- D. The Olfactory Receptor

6. Liquids

- A. Hydrogen Bonding
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- C. Hydrophobicity
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- A. Allotropes of Diamond
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8. Ices

- A. Hexagonal Ice
- B. Cubic Ice and Other Ices

9. Chemical Reactions

- A. Combustion Reactions
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- C. Nitrogen Fixation

10. Plastics

- A. Polymerization of Ethylene
- B. Polypropylene Tacticity
- C. Atactic Plastic Polymers
- D. Polyester Plastic

Course scope and purpose

Biochem 2.0 Unit 1, Panorama is for everyone!

This is the first unit in the Biochem 2.0 program, which will eventually replace the classic program that was created in 2019. This course has been informed by my work teaching hundreds of Zoom classes, and is a huge upgrade in quality and scope, compared to the original program, which of course is still extremely useful, and will continue to be used as the program is upgraded.

Scope and approach

This unit is a survey of chemistry and biochemistry, and orients students to the field, and gives them the skills they will need to continue on with the program. But it was also made as a stand-alone course that teaches students to have a molecular outlook on life. Many of the topics are high school level, and we even touch on some more interesting and obscure content. The unit provides a wide scope of learning experiences that triangulates biochemistry within several other fields, including biology, chemistry, materials science, astronomy, and synthetic chemistry. The strength of this unit is that it only uses on concrete, easy to understand ideas to teach chemistry. In later units, we will cover more abstract concepts and calculations that are typical of high school chemistry, but in Unit 1 should be accessible to virtually any student from any background or skill level. The custom model kit is strongly leveraged throughout the unit, to make the experience more active, and to allow for more durable learning.

Why should kids learn this?

Biochemistry is at the heart of science and connects biology to other fields. Because it requires mastery of chemistry to understand, and is a relatively new field, traditional education still does not include much biochemistry. But biochemistry informs many aspects of everyday life, from understanding nutrition and medicine to the environment and our senses. There is an incredible amount of knowledge that is simply neglected by science curricula. My classic Biochemistry Literacy program unlocked an effective and ambitious methodology that enabled kids to learn about chemical bonding quickly, so that they could study high level topics like protein function. This new Biochem 2.0 program goes a step further and, and leverages years of experience teaching Zoom classes, and augmenting the content. It also incorporates more features, including photographs of This curriculum frames the world around biochemistry, and should motivate and excite kids to study

Landscape of the course and Lab activities

Biochem 2.0 is not just a series of lessons. It reviews, iterates, and applies concepts as the student learns. The lessons are interconnected into a unified story. One section may incorporate references to earlier content, connect it to biology, apply it to industry, and frame it in the context of human history. The lessons are visual and tactile. Unit 1 is just the introduction to the course, and most active learning involves model building with the custom kit. But I have added a few simple laboratory suggestions to demonstrate some of the chemical and enzymatic reactions that I discuss. These are safe and use everyday materials. Later units will incorporate more lab experiences.

Outlook and school science

Unit 1: Panorama give students a panoramic view, a lay of the land of chemistry and biochemistry and how they connect to the rest of science. This unit contains rich content, but is not a substitute for high school chemistry. It is meant to give students the chemical knowledge needed to delve into the more advanced content of later units. Unit 1 gives students to think competently about the molecular nature of the world; Unit 2 give students the hardcore knowledge needed to understand how it all works. There, we will study atomic structure, justify with theory the bonding rules discovered in lesson 1, and flesh out many areas needed to understand protein structure, which is the main focus of Unit 3, Kaleidoscope. By the time students complete Unit 2, they will have completed most of the non-quantitative side of high school chemistry. The classic Biochemistry Literacy lessons cover most of high school biology. Eventually will create additional units that complete the content typically required of these school subjects.

Content

The program begins, assuming that students have no background in chemistry. There is no need to prep kids for the program. Depending on their age and reading level, students may benefit from adult help, but generally, all directions are visual and spoken, and the presentations typically have minimal text. This is designed for everyone!

Lesson 1 begins by introducing molecular modeling, and teaches students how to predict the bonding behavior of the most important atoms in biology. Throughout the course, students refer back to these molecules and develop their understanding of them and their applications to their function in nature and their uses for humans.

Lesson 2 covers the composition of planetary atmospheres. This may be a surprising including so early in the course, but this topic gives us the opportunity to practice identifying some of the most important molecules we will study, and orients students to the connection between the atmosphere and biology.

Lesson 3 gives students their first experience of drawing molecules and interpreting molecular drawings. We use NSAID pain relieving drugs as models for our drawing. We also see our first enzyme structure, the COX-2 enzyme, which is the target for the NSAID drugs. Students see their first example of ligand binding and the inhibition of an enzyme.

Lesson 4 covers the biology of hemoglobin, connecting gases in the air to our physiology. Students gain an appreciation for protein structure in this lesson, building excitement for what's to come in later units.

Lesson 5 teaches students how to write and interpret professional chemical drawings. We use aroma molecules to add a fun dimension to this unit. As they learn to draw, they also learn how to classify aroma molecules based on molecular structure. We also see our first protein, an odor receptor protein, whose structure was only recently solved. We also cover the concept of the isomer—a molecule with the same formula as another molecule, but with a different structure.

Lesson 6 moves from gases to liquids. We go through a virtual experiment, in which students deduce why water has such unique properties. The lesson covers the concept of hydrogen bonding, an extremely important concept in biology. We explore the nature of liquids and introduce the concept of water solubility and oil solubility.

Lesson 7 introduces a selection of solids, and reveals how their structures differ from those of liquids and gases. Students learn the concept of the allotrope—different forms of an element that have different bonding patterns. This unit is important because it helps students understand that solid objects have an atomic nature, and that they differ from liquids and gases in their structure.

Lesson 8 highlights some interesting detail about water ice, as well as other ices. Students learn why some materials form solids easily and others need to be cooled to extreme temperatures in order to freeze. We apply the concept of hydrogen bonding.

Lesson 9 introduces the concept of the chemical reaction, as well as equation balancing, and lays the groundwork for understanding thermodynamics, kinetics, and catalysis. Reactions that occur spontaneously are contrasted with those that occur enzymatically.

Lesson 10 teaches the polymer concept through the simple model of plastics. The polymer concept will be used later in the course when students study biopolymers like proteins. Covering the molecular nature and synthesis of plastic gives and strengthens students' molecular outlook by connecting them to objects that they interact with every day. The simplicity of plastic's structure gives a unique opportunity for students to feel competent in that they can understand the molecular basis of the world around them.

Workbook excerpt

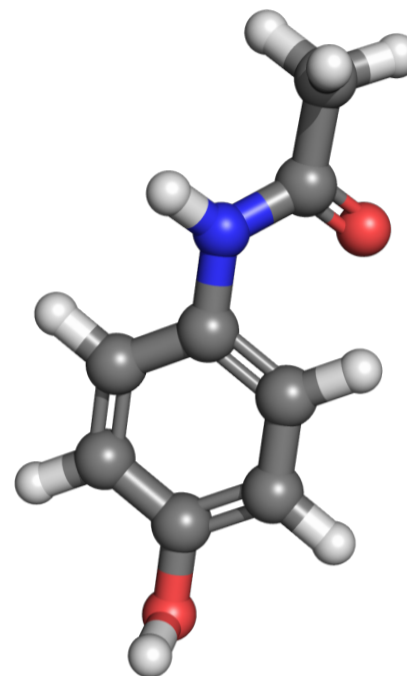
You can watch the free sample video, Lesson 1 as you work through the follow pages.
Keep in mind that the model building with the custom kit is an essential part of learning,
and is the secret to success for younger learners.

Lesson 1A

Molecular Modeling: Hydrocarbons

Before class question: Write down anything that you know, or can observe, about the following structure. Save your response to this question. We will compare what you wrote here to what you write after you complete this unit.

Write your answer here.



Welcome to Biochemistry Literacy!

This is your workbook. You should also have a blank notebook where you can write down facts that you learn, questions you want answered, and importantly, the molecular structures we will be learning about. Please use your notebook a lot. The more you write, the faster you will learn. Please do not just watch the videos. Have your model kit available for all the lessons, and build every molecule that you can. Building is the best way to learn biochemistry!

Optional: It may be nice to have a camera or phone on hand so that you can record images of some of the models. You may like to create an archive of many of the models that you make in this course. I don't think you need to photograph every molecule, but recording some of your creations may be a nice way to remember what you are learning.

Please begin the video for Lesson 1 now, and use this workbook and your blank notebook as you watch. There will be prompts to write or build in the video, but you can also take your own notes and explore building on your own. Pause the video as much as you like when you are building or drawing. You can also watch the video first and draw and build afterwards. Do what works for you.

Color your periodic table.

On the following page, use colored pencils to color in the element symbols that we introduced.

Build all the models.

Starting with methane, build all the molecules in this lesson. You do not need to draw them now. In Lesson 3, we will learn how chemists draw molecules. You cannot have all the molecules built at the same time. For example, your model kit does not have enough pieces to have all the hydrocarbons constructed at once. Feel free to add to these structures and photograph them, as you build.

In your notebook, take notes.

Write down information that you find interesting, or think is important, as you watch the video. Memorizing the molecules methane, ethane, propane, and butane, for example, is important. You can record the mnemonic device "must eat peanut butter" so that you can remember their names.

1	H Hydrogen	2	He Helium	3	Li Lithium	4	Be Beryllium	5	B Boron	6	C Carbon	7	N Nitrogen	8	O Oxygen	9	F Fluorine	10	Ne Neon												
11	Na Sodium	12	Mg Magnesium	13	Al Aluminum	14	Si Silicon	15	P Phosphorus	16	S Sulfur	17	Cl Chlorine	18	Ar Argon	19	K Potassium	20	Ca Calcium	37	Rb Rubidium	38	Sr Strontium	55	Cs Cesium	87	Fr Francium				
21	Sc Scandium	22	Ti Titanium	23	V Vanadium	24	Cr Chromium	25	Mn Manganese	26	Fe Iron	27	Co Cobalt	28	Ni Nickel	29	Cu Copper	30	Zn Zinc	31	Ga Gallium	32	Ge Germanium	33	As Arsenic	34	Se Selenium	35	Br Bromine	36	Kr Krypton
39	Y Yttrium	40	Zr Zirconium	41	Nb Niobium	42	Mo Molybdenum	43	Tc Technetium	44	Ru Ruthenium	45	Rh Rhodium	46	Pd Palladium	47	Ag Silver	48	Cd Cadmium	49	In Indium	50	Sn Tin	51	Sb Antimony	52	Te Tellurium	53	I Iodine	54	Xe Xenon
71	Lu Lutetium	72	Hf Hafnium	73	Ta Tantalum	74	W Tungsten	75	Re Rhenium	76	Os Osmium	77	Ir Iridium	78	Pt Platinum	79	Au Gold	80	Hg Mercury	81	Tl Thallium	82	Pb Lead	83	Bi Bismuth	84	Po Polonium	85	At Astatine	86	Rn Radon
103	Lr Lawrencium	104	Rf Rutherfordium	105	Db Dubnium	106	Sg Seaborgium	107	Bh Bohrium	108	Hs Hassium	109	Mt Meitnerium	110	Ds Darmstadtium	111	Rg Roentgenium	112	Cn Copernicium	113	Nh Nihonium	114	Fl Flerovium	115	Mc Moscovium	116	Lv Livermorium	117	Ts Tennessine	118	Og Oganesson

57	La Lanthanum	58	Ce Cerium	59	Pr Praseodymium	60	Nd Neodymium	61	Pm Promethium	62	Sm Samarium	63	Eu Europium	64	Gd Gadolinium	65	Tb Terbium	66	Dy Dysprosium	67	Ho Holmium	68	Er Erbium	69	Tm Thulium	70	Yb Ytterbium
89	Ac Actinium	90	Th Thorium	91	Pa Protactinium	92	U Uranium	93	Np Neptunium	94	Pu Plutonium	95	Am Americium	96	Cm Curium	97	Bk Berkelium	98	Cf Californium	99	Es Einsteinium	100	Fm Fermium	101	Md Mendelevium	102	No Nobelium

Lesson 1B

Molecular Modeling: Hydrocarbons

Build all the models.

Use the long bond pieces to build the double and triple-bonded molecules. Write down in your notebook the names of the molecules we are studying. It is not necessary to memorize all the names of the molecules now, other than the following four very important molecules.

Write the formulas for these molecules and learn their structures.

Methane:

Ammonia:

Water:

Benzene:

In your notebook:

Define the word isomer and build an example with your kit.

Describe the difference between *cis*-diazene and *trans*-diazene.

Lesson 1C

Molecular Modeling: Bonding Rules

What molecules and atoms make up the air?

What is the main difference in spacing between molecules between air and water?

Fill in the chart below to summarize the bonding rules that we have learned so far.

	Symbol	Atom color	Bonds	Electron lone pairs
Hydrogen				
Carbon				
Nitrogen				
Oxygen				
Fluorine				
Neon				

Write the numbers for the 4, 3, 2, 1 rule on your periodic table above the element columns. For example, write 4 above carbon's symbol.

Assignment:

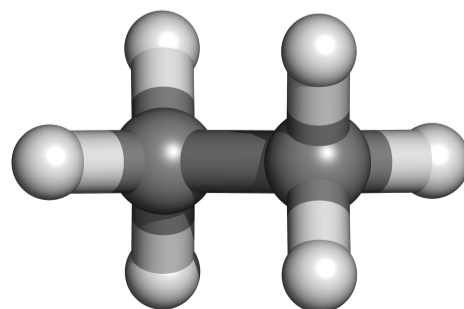
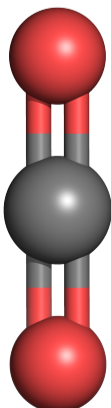
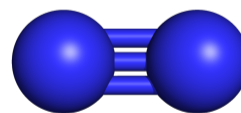
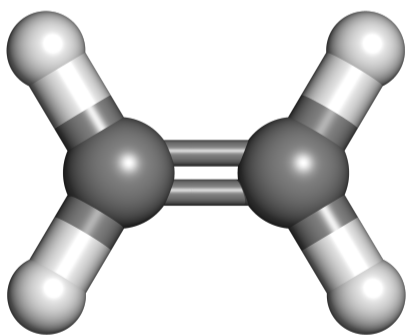
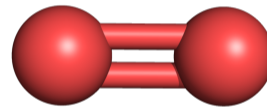
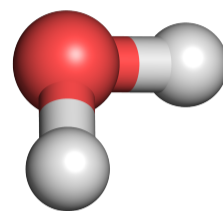
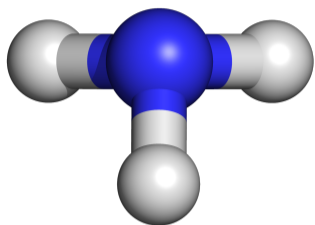
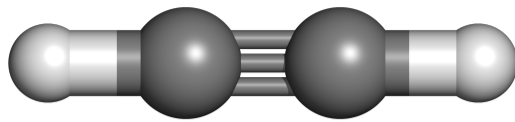
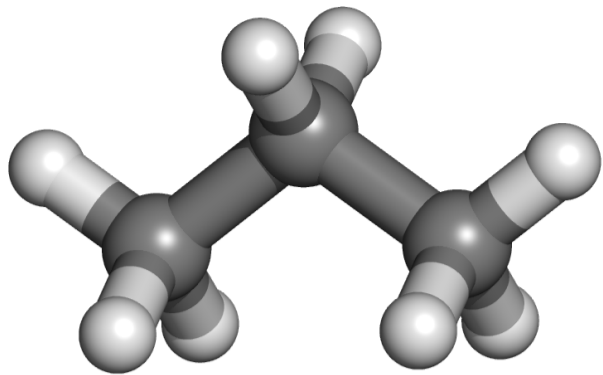
Build your own molecule based on the rules and trends that we have seen in molecular construction. Take a photo of your creation and add it to your photo journal. Be sure to check that your molecule follows these rules and trends:

1. It follows the 4, 3, 2, 1, rule.
2. It uses mostly carbons and hydrogens.
3. It feels relaxed and not stressed.
4. Optional: It contains medium sized rings or 5 other 6 atoms.
5. It contains double or triple bonds.

Lesson 1 Flash Cards

Print these cards on the two-sided setting with a color printer.

Cut out these flash cards to practice the 13 most important molecules from this lesson and the atom color coding for the 7 most commonly seen atoms.



Ethyne

Propane

Water

Ammonia

Oxygen gas

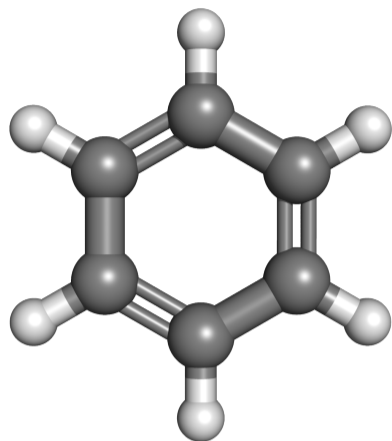
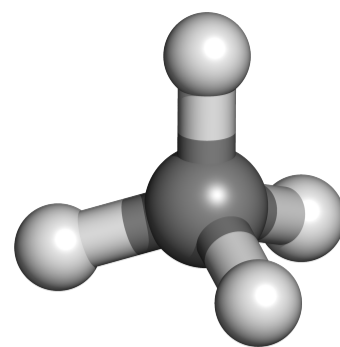
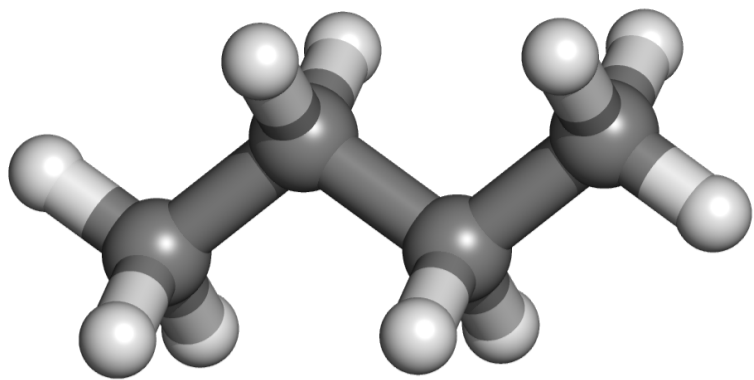
Hydrogen gas

Nitrogen gas

Ethene

Ethane

Carbon dioxide



Black

Red

Blue

Light green

Forest green

White

Yellow

Methane

Butane

Carbon

Benzene

Nitrogen

Oxygen

Chlorine

Fluorine

Sulfur

Hydrogen

Lesson 1

Molecular Modeling: Additional Reading

The molecules that make up living things are based on carbon and hydrogen. Life on Earth is therefore “carbon-based”. Because carbon is so important to life, we begin studying biochemistry with hydrocarbons—molecules rich in hydrogen and carbon.

In this lesson, we learned that carbons make 4 bonds, nitrogens make 3 bonds, oxygens make 2 bonds, and fluorine makes 1 bond. Noble gases like neon do not make bonds. The reason living things contain so many carbon-rich molecules is because carbon can make the most bonds. There is therefore a huge variety of possible molecules that can be made from carbon. Carbon-carbon bonds are also very stable, compared to nitrogen-nitrogen bonds and oxygen-oxygen bonds. There is a huge number of possible carbon rich molecules, and in this course, we will study the most important ones that nature has selected as the building blocks of life!

The molecules that you learned in this lesson are simple, but they are very important for us to understand the structure of bigger, more complex molecules. Please try to memorize their names, especially the 13 that appear on the flash cards. Notice that carbon-rich molecules also contain many hydrogens. Often molecules are “coated” in hydrogens. This is a common arrangement, so if you are experimenting with your model kit, remember to connect hydrogens to your carbons, but not too many oxygens and nitrogens. Biomolecules tend to have fewer oxygens and nitrogens, compared with carbons and hydrogens.

In biochemistry, rings of atoms, as well as double bonds, are also very common. Benzene is a famous molecule that is the building block of other ringed molecules. Benzene itself is a toxic liquid, but benzene, and molecules like benzene, can commonly be found in biomolecules. As you experiment with building, try to include medium-sized rings of 5 or 6 carbons. These are by far the most common ring sizes in molecules. Later, we will learn that bigger and smaller rings are possible, but are less common.

Some atoms also have lone pair electrons. Carbon has no lone pair electrons, while nitrogen has one, and oxygen has 2. Fluorine has 3 lone pairs, but our model kit does not allow us to attach them. We will learn later in the course how the lone pair electrons are important for understanding how molecules behave.

Lesson 1

Molecular Modeling: Vocabulary

Atom: We symbolize atoms with the round pieces in our model kit. Each color represents a different element. We will learn more about the structure of atoms in the next unit.

Molecule: Molecules form when atoms are bonded together. Our model kit is designed to model molecular structures.

Bond: Bonds are made up of shared electron pairs, and are symbolized by the gray pieces in our kit. In the next unit, we will learn how bonds form.

Lone pair of electrons: These are electron pairs that are not part of bonds. Throughout this course, we will understand more about what lone pair electrons do. We represent them with the tan pear-shaped pieces in our kit.

Tetrahedron:

The geometric shape created by a methane molecule, ammonia (including its lone pair of electrons), and water (including its lone pairs of electrons) is called a tetrahedron. In methane, the carbon has 4 bonds, which extend out at an angle of 109.5° , creating a tetrahedral geometry around the atom.

Formula: The molecular formula presents which elements, and how many of each, are found in a molecule. Typically, the elements are ordered H, C, and then the other elements in alphabetical order—however this is not always the case.

Isomer: Molecules that have the same formula, but with their atoms connected differently are isomers. Some molecules don't have isomers, such as methane. The larger the molecule, the more isomers are possible. However, not all isomers are stable or common. Just because it can be modeled with your kit, does not mean it is a real molecule.

More about the custom model kit

With every lesson, students will learn more and more about how the model kit works. The components of the kit are shown below. Students will learn the Corey-Pauline-Koltun (CPK) color coding for the elements, but keep in mind that we can use the atoms available in the kit to model other atoms. For example, we use the metallic atom piece to represent iron in lesson 4, but we may use it to represent other metals. Also, we typically use the black atom pieces to represent carbon, but we may also use them to represent silicon, as it has a similar bonding behavior.

There are a few pieces that are the same color, but have a different number of bonding holds. For example, there are two kinds of white hydrogen pieces, and two kinds of blue nitrogen pieces. In lesson 7, we will learn what to do with the 2-hole hydrogen pieces. The 3-hole nitrogen piece has a specialized use which will be introduced in later lessons, so students can ignore it for now.

The number of holes in an atom does not necessarily mean that the element can make that number of bonds. Lone pair electron cloud pieces are also added to certain atoms, and students will learn how this works during the first unit. You will also notice that there are two kinds of gray bond pieces. The short pieces are used to represent single bonds. The long flexible pieces are used to represent double or triple bonds. There is nothing wrong with using the long bonds for single bonds, but typically this is not done.

What if I want additional atoms for building?

Once you have one of the custom kits, your student can model all the unique concepts that the kit makes possible. Some students want to build bigger molecules and run out of pieces. Since the lone pair electron pieces in particular are expensive, the most economical solution to expanding your set is to not purchase more of my custom kits, but to purchase standard kits like the ones listed below.

Molymod MMS-008: This set is similar in size to the custom kit and is the one typically purchased by college organic chemistry students. It lacks several of the specialized pieces, and cannot model hydrogen bonding, but it will let your student build larger molecules.

The **Molymod MMS-009** is an inorganic set, and has additional atoms that represent various metals with different bond geometries.

The **Molymod MMS-003** is an “teacher sized” kit and will give your student many more atoms.