Stoichiometry will save your life

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This curriculum unit is recommended for:
High School Science classes

Keywords: stoichiometry, moles, grams, empirical formulas, molecular formulas, calcium supplements

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis:

This curriculum unit focuses on using dietary supplements and drugs to discuss the math around stoichiometry. The intent is to make my stoichiometry unit more interesting and relevant to student lives. For calculating basic mole/mass/particle conversions we will look at calcium supplements. Drugs and other dietary supplements will be the focus of empirical and molecular calculations. We will return to calcium carbonate when looking into stoichiometry in an experimental setting. Students will ultimately determine how much calcium ions will be produced from the reaction of various calcium carbonate items (eggshells, Tums, chalk) with hydrochloric acid.

I plan to teach this unit during the coming year to 100 students in Honors and AP Chemistry.

Introduction

"The aims of pure basic science, unlike those of applied science, are neither fast-flowing nor pragmatic. The quick harvest of applied science is the useable process, the medicine, the machine. The shy fruit of pure science is understanding."

- Lincoln Barnett[1]

We're often called upon as teachers to take our content area and give real world relevance to what we're teaching. This can be difficult for some of the more basic topics in science. How do I take atomic structure and make it have relevance to the everyday life of my students? There are some topics that are easy to relate to what we do in our everyday life. How does that battery work in your smart phone? Both are topics in chemistry. And when students don't see that real world relevance, many of them get lost. These are the students are looking for applied science. They want to know "why is this useful?" While that is not an invalid question, they often get so stuck on that question that they have trouble simply understanding or answering the question of "why is our world like this?" Ultimately that's the most basic goal of science: to understand our world and develop theories that explain what we see in our world.

I do my best to find real world relevance to each topic we cover because I understand that not all students have a love for the understanding. They love the usefulness. The immediate, pragmatic, this is where this is used in my life. My goal for this curriculum unit is to bring some of that relevance to stoichiometry by having students study calcium supplements and compare which would be better to take to get their daily recommended amount of calcium.

Rationale

The concise description above probably does not explain well what exactly my plan with this unit it so let me explain that here. Over the last four years of teaching chemistry, I am getting bored with the current way we teach our curriculum and looking to make changes that will keep both myself and my students interested. While I love learning and just learning for learning's sake is enough to keep me interested in a class, this is not the case for my students. They need something to pull them into the material. And I'll admit that right now, I feel like that part is lacking.

During my CTI seminar last year, I discussed the book "Minds Made for Stories" by Thomas Newkirk with my seminar coordinator. People, in general, tend to retain and enjoy information that is in a story form. We look tend to look for cause and effect, for the overarching macroscopic things in life. Chemistry tends to go for the microscopic stuff in life. And we often get lost in the little details. We don't see where they can be used the bigger picture of our lives.

Over the summer I worked to redesign much of my way of delivering course work for next year by putting it in the form of a stories or real world situations. For some of my lessons I use the premise will be that the students in my class are on a space ship that launched from Earth to go colonize another planet. During the trip some disaster happens that means the ship has to crash land on a nearby habitable planet and they must survive and find a way to communicate back to Earth where they are so they can get help. For other lessons, I look for real world today issues that we can discuss with our content.

This unit will focus on real world issues of today. Dietary supplements are prevalent in our society and it's difficult to know if they're helpful or not. It's also difficult to know if you can trust what you read on a label with dietary supplements are not as regulated as drugs. You could get exactly what it says or it could have some discrepancies in amounts. We can use mole conversions and stoichiometry to check the labels on dietary supplements to see if what is told to us is accurate in comparison to what we can calculate.

I am hoping that by creating this unit for my curriculum that I will spice up what I feel has, in the past, been unengaging. It will allow me to use my creativity and to hopefully find some more joy in teaching my curriculum again. If I'm bored, then it can't be good for my students.

School/Student Demographics

William A. Hough High School is located in the North Learning Community of CMS. The student population comes from a largely suburban and rural background unlike many of the schools throughout Charlotte. We have over 2,700 students. Our school is growing bigger and bigger each year.

One of the great things about Hough High school is the community involvement. There are many community outreach programs that help the school. The biggest of which is our partnership with Bailey's Glen. They are a local retirement community that helps to raise funds for our school so that teachers and students can obtain some funds for school supplies they might not otherwise be able to obtain.

That said, our students do face some challenges as they are still teenagers. There are still poverty issues with several families at Hough even though we are in a suburban area. There are still students for which English is a second language and struggle with course content because of that. There are still students who have disabilities.

The largest problems that our demographic has is the pressure to achieve and do well in their high school career. Many of our students will go on to college and many have great ambitions for what colleges they would like to be accepted into. Thus there is internal pressure on the student to do well so they can get into their choice college. Because of this, many high flyers at our school take several AP classes, head a club and are on some type of sports team. This internal pressure to achieve can see many students reach a burn out point.

As they are teenagers, they also have typical teenager problems as well. Motivation and determination can be issues for our students. They are used to knowing the answer right away or being able to find it easily, thus when an answer doesn't present itself immediately, they can become disheartened and give up. As the AP chemistry teacher, I see this first hand when they reach my class and they have never been truly challenged until then. It causes them to have to rethink who they are. They are no longer the student that 'gets' things easily but a student that needs to work hard. We all reach something in our lives that does not come easily to us. We have a choice at that point: give up or persevere.

A majority of those students will end up taking chemistry as there is a push for students that are going to go on to college to take Chemistry for their physical science class. In my classroom, I have anywhere from 20 to 40 students depending on the level of the class. My standard chemistry classes are usually under 30 students, my honors chemistry classes are usually over 30 students and my AP chemistry class can be anywhere from 15 to 25 students. As I teach all levels of chemistry I want to make this curriculum unit accessible to all levels of chemistry.

Unit Goals

Problem Solving

This goal tackles both the topic (stoichiometry) and the bigger premise of the class or groups of students in the class solving a problem. Stoichiometry in and of itself is a class of problems that need to be solved by reading a word problem, determining what values are important and then using those values to convert from one set of units to another set of units (dimensional analysis). Students often struggle with the concept because there are several steps that might be involved in a stoichiometry problem. They can't immediately see the pathway to solve it and there isn't one equation that the numbers are just plugged into. It takes more thought than that. This often means that students give up because they cannot immediately see the solution to their problem or the way to solve it.

In the past, I have used various mole maps and diagrams or other organizational methods to help students understand the process. But they often feel at this point in the semester that there's no point to ever really understanding the material because they can't see its use.

The problem solving in this unit will focus around analyzing information about dietary supplements and other drugs to use real world examples of where the content of the stoichiometry unit can be used. We will use to this information to determine which calcium supplement from a list of options will be better for us to take if we were deficient in calcium

Lab Analysis Skills

Students will in the final lesson react calcium carbonate containing substances with hydrochloric acids to determine how much calcium ions are freed from the original substance. Since many of the calcium containing supplements are oral, they would enter the stomach and react with the acid there so this seems a good simulation of what might happen should a person take the supplement.

For labs, I put my students in groups so each group would get a different calcium carbonate containing substance. Each substance would ultimately be treated similarly and need the same kind of mathematical analysis for determining the amount of calcium ions such as mole/mass/particles conversions and limiting reactants analysis.

Students often struggle with analyzing data from lab and see how it actually fits into what we are talking about. So this should be supplemented by class discussion of the data found.

Content Research

Important Background Information

Vocabulary in this unit is important. There are a lot of terms that we tend to use in a colloquial manner that are actually more nuanced that we realized. So to start, let's define some of the more common terms that we use throughout this seminar so we are clear about how they should be used when we talk about them with students. The definitions we are going to use in this curriculum unit go back to the Federal Food, Drug and Cosmetic Act (FD&C Act).[2]

- Drugs: defined as "articles intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease articles (other than food) intended to affect the structure or any function of the body of man or other animals."[2]
- Cosmetics: defined as "articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body...for cleansing, beautifying, promoting attractiveness, or altering the appearance."[2]
- Dietary Supplements: defined as "a vitamin; mineral; herb or other botanical; amino acid; dietary substance for use by man to supplement the diet by increasing the total dietary intake; or a concentrate, metabolite, constituent, extract, or combination of the preceding substances."[3]

These are the three main definitions within the realm of the FD&C Act that we need to focus in on. It is important to note that cosmetics and dietary supplements by the definitions above are not intended for use in diagnosis, cure, mitigation, treatment or prevention of disease. This is an important difference as this is the sticking point as to what approval routes a chemical needs to go through. Drugs have a far more exhaustive approval method than cosmetics or dietary supplements.

The intended use of a product is established in one of three ways: claims stated by the product, consumer perception and ingredients used.[2] It is entirely possible that a product can be considered by the FDA to be a drug even if it were marketed by the company as a cosmetic or a dietary supplement. If this happens then the company might get a letter from the FDA about this issue. This means they may have to pull their product until they go through the necessary routes of drug approval.

Appendix 2 contains a diagram of "Drug Discovery and Development Timeline.". In the drug pre-discovery phase, a company that makes drugs looks through their library of one to two million compounds and tests all of their compounds for ones that have markers that could potentially affect whatever disease they're looking into. This narrows down the field of potential drugs to somewhere between 5,000 and 10,000. Ultimately, chemicals are narrowed down based on patient issues, predicted metabolism and toxicity. At this point the drug company has around 5-10 leads that they will explore more. These are optimized by changing their structures. These optimized leads are then put through pre-clinical trials. These involve animal testing experiments. This further narrows the field of potential drugs. These two steps can take anywhere from 3 to 6 years.

If a potential compound has shown promise at this point, the company will patent it and file an Investigational New Drug (IND) application with the FDA. If this is approved, then the company to move on to clinical trials of their drug. It is important to the company that they start to get results at this point. If they've patented a compound, then they now have a ticking clock on the compound being exclusively theirs.

Clinical Trials are divided into three phases and can take an average of 6-7 years. Phase 1 has around 20-100 volunteers that are healthy young men and women. In this phase, the company is mainly focusing on the safety of the drug. Phase 2 has around 100-500 volunteers that have whatever disease that the drug is intended to be use for. Here the company is testing the efficacy of the drug. Does it work as intended and at what dose does it work? In phase 3, 1,000 to 5,000 volunteers are used to test the efficacy of the dosed drug. All of this data is compiled by the drug company and sent to the FDA in an application called the New Drug Application (NDA).

If the FDA approves the NDA, then the drug can be distributed to pharmacies and doctors can prescribe the drug to patients. At this point, the drug is in what is often called Phase 4. It continues to be monitored for any dangers or lack of efficacy. It could be pulled even at this point and approval revoked.

ADME

ADME stands for absorption, distribution, metabolism and elimination. These are the processes that drugs go through once we take them.

Adsorption is how the drug get to the blood stream. Different drugs have different bioavailability and absorption abilities. Some are better given to you orally while others need to be intravenous.

Distribution is how the extent to which a drug stays in the blood or enters the body's other tissues. Some drugs get sent through the bloodstream to different areas of the body more easily while other drugs stay within the blood stream. Drugs that get sent to other areas of the body take longer to get to the metabolism step while those drugs that stay with in the bloodstream are more easily metabolized.

Metabolism is where the drug is broken down and other pieces are added to it to ultimately make it easier to eliminate. This typically happens in the liver or the kidneys.

Elimination is how the drug leaves your body. This most often occurs through urine and feces.

Drug specific information to this unit

All of the above is fascinating stuff but I need to take that and somehow many it applicable to my class. Drugs are complex chemicals. Often with structures that are too difficult for the high school student to understand seeing as we mostly focus on inorganic chemistry at the high school level. Drugs tend to be organic molecules. So for this unit, I will be focusing in on a dietary supplement as a model to use: Calcium supplements.

Most students have heard of calcium before they enter my class. They know milk contains calcium and that calcium intake is important for healthy bones. What they don't often realize that is that it's not just elemental calcium that we're talking about. The average person says calcium but the chemist knows that we're talk a calcium salt of which the calcium ion is what is important for us.

Calcium is important to our diet. As the fifth most abundant element in the human body we need it to thrive. It makes up about 1.5-2.0 % of our total body weight.[4] That doesn't sound like it's that important at all but just small fluctuations in that range can cause many problems for us. Most of our calcium is contained in our bones. Think of this as a reserve. If we do not take in enough calcium in our diet, then out body must take it from our bones and we lose skeletal strength and bone density.[4] This can lead to bones breaking easily. Calcium is also used for enzyme activation, nerve transmission, regulation of heartbeat, and blood clotting.[4] A calcium deficiency can cause different issues in children versus adults. Children can develop rickets and abnormal bone growth while adults can develop osteomalacia and osteoporosis.[4]

It is recommended that a person have about 700 mg of calcium daily.[4] The best source of calcium for us are milk, dairy products, fish, beans and dark vegetables. There are several commercial calcium salts that can be taken as supplements such as:

- Calcium carbonate
- Calcium phosphate
- Calcium citrate
- Calcium lactate
- Calcium gluconate
- Calcium lactategluconate

This can make it difficult to make a decision on which calcium supplement might be best for you if you can't take in calcium the natural way. An analysis of these supplements using stoichiometry can help us to determine which one would be the best one for us. Gabriel Pinto's paper on calcium medicines gives a table of masses of calcium in selected medicines.[3] See appendix 3 for this table.

Stoichiometry

Stoichiometry deals with the quantitative relationship between chemical formulas and equations. Chemical formulas tell the portions of atoms within a chemical equation. For example, if you look at the chemical formula for calcium carbonate, $CaCO_3$, the ratio is 1 calcium atom to one carbon atom to three oxygen atoms. This ratio could also be put in terms of ions: one Ca^{2+} ion and one CO_3^{2-} ion.

As for chemical equations, the proportions of masses, atoms and moles can be deduced from a chemical equation. For example, the reaction of calcium carbonate with hydrochloric acid:

$CaCO_3 + 2\ HCl \rightarrow CaCl_2 + H_2O + CO_2$

In this reaction, we can say that 1 mole of calcium carbonate reacts with 2 moles of hydrochloric acid to produce 1 mole of calcium chloride, 1 mole of water and 1 mole of carbon dioxide. We can then use those molar ratios along with given information about how much of our reactants we started off with to determine how much of our products could be produced. For example we could ask the following question:

2.0 grams of calcium carbonate are reacted with 10 mL of 6 M HCl. How many grams of calcium chloride would be produced?

Step 1. Find the limiting reactant.

$$2.0\ g\ CaCO_3 \times \frac{1\ mole}{100.1\ g\ CaCO_3} = 0.02\ moles\ CaCO_3$$

$$6\ \frac{mole}{L} \times 0.01\ L = 0.06\ moles\ HCl$$

$$0.06\ moles\ HCl\ \times \frac{1\ mole\ CaCO_3}{2\ mole\ HCl} = 0.03\ moles\ CaCO_3$$

In order for all of the HCl to react, you would need 0.03 moles of $CaCO_3$. You only have 0.02 moles of $CaCO_3$. This means that the calcium carbonate is the limiting reactant and will tell us how much calcium chloride can be produced.

Step 2. Calculate the amount of calcium chloride that could be produced in grams.

$$0.02\ moles\ CaCO_3 \times \frac{1\ mole\ CaCl_2}{1\ mole\ CaCO_3} \times \frac{111.1\ g}{1\ mole\ CaCl_2} = 2.22\ g\ CaCl_2$$

However, when a reaction occurs, it doesn't often go to 100% completion. Often we don't make as much of a product as we predict we make when we perform a lab. This is due to most reactions being equilibrium reactions (meaning that they can actually go in the forward and reverse directions) and not complete reactions (all reactants react to make products). This can also be due to human errors and some of the product getting lost during transfer from reactant vessel to weighing boat or paper.

What this means is that we can calculate percent yield when we perform a reaction. Say that we performed the previous example in a lab and we massed out our product to be 2.02 grams total. Then to calculate percent yield we would do the following:

$$\frac{2.02\ g}{2.22\ g} \times 100 = 91\%$$

We would have a 91 % yield. So we lost about 9 % of our product either to human error to the reaction not going to completion.

These are some of the basic mathematical and problem solving skills that both teachers and students would need for this unit.

Instructional Implementation

This curriculum unit will span the entirety of the stoichiometry unit that we cover in class. This unit is generally lasts about 8 days and is divided into the following topics:

- Intro to Moles: We review basic mole conversions going from grams to moles to particles and in the reverse. We often use some variation of showing a mole diagram of how to road map these calculations
- Using Moles with formulas: We talk about percent composition, calculating empirical formulas and calculating molecular formulas
- Stoichiometry: We bring in mole conversions and relate them to the chemical reactions we studied in the previous unit.

Teaching Strategies

Cooperative Groups
In my classroom, I use cooperative groups. I put student in groups of 3-4 to work together. Each unit, I switch up the groups so that students get to engage and talk with almost everyone in the class at some point throughout the semester.

Within my cooperative groups, I give them roles with different responsibilities

- MedTech
    - Is supportive of group members that are having trouble. Notes areas where the group is doing well and where they could improve.
    - Checks answers for the group.
    - Observes and comments on group dynamics and behavior with respect to the learning process.
    - May be called upon to report to the group (or the entire class) about how well the group is operating (or what needs improvement) and why.
    - This person is also responsible for reporting orally to the class when called for in class discussions

- Engineer
    - Gathers materials needed (especially for labs).
    - Records the names and roles of the group members at the beginning of each activity.

    - Records the important aspects of group discussions, observations, insights, etc.
    - Their report is a log of the important concepts that the group has learned.

- Command
    - Manages the group. Ensures that members are fulfilling their roles, that the assigned tasks are being accomplished on time, and that all members of the group participate in activities and understand the concepts.
    - Reads the activity out loud to the group.
    - Must monitor their volume so that their group can hear them, but other groups are not disturbed.
    - Helps keep everyone in the group together.

This has helped students to keep on task and know what they should be doing during an activity.

While my class revolves around students working together, this does not mean that they don’t have individual practice as well. This also doesn’t mean that the lessons in this curriculum unit couldn’t be adapted to be individual assignments.

Modeling Problems

With mathematical problems, students need to see example problems modeled by the teacher. This helps students understand how to read a word problem and take pertinent information from the problem. The teacher should model how they think through a problem. This can best be done by talking through how you problem solve and slow down how you think into smaller steps. Some students will follow the model while others will forge their own way. It at least gives them a direction to start.

Whiteboard Presentations

In this strategy, a small group of students are given a problem to solve and are expected to display it and all work on a whiteboard for presentation to the class. From here it can go one of two ways.

Each group can present their problem to the class as a whole and the class can examine the answer. If possible, the teacher should try to lead the class to analyze if there is anything wrong with the work on the board instead of stepping in and saying if it is correct or incorrect. Students recognition of errors in work is helpful to their learning. This means that expectations for this need to be established before the first group presents. There should be a class discussion about how we need to be respectful of other’s mistakes when they’re learning because everyone makes mistakes. Stems to start a respectful discussion should be given such as:

- I see it differently because…
- The evidence I’ve seen suggests...

For classes in which confidence in ability is low, then a gallery walk of the whiteboards with post it note feedback from each person might be a better option. The two sentence stems should probably still be given so that the feedback is meaningful and constructive if the work is incorrect.

Sentences stems could also be used to for when students agree on the work as well. Such as:

- I agree because…

This strategy can be very effective in getting students analyze and talk about each other's work if the correct classroom environment is established.

Labs

Labs are an important part of my teaching strategies. We usually do at least one lab a week in each of my classes because one of the skills my students need to work on is analyzing lab data and relating it to the content we learn. To them labs are fun things we do that get ruined by calculations they don't want to do.

However, I continue to fight the good fight of getting them to analyze their data because that's part of what science is. We can't just mix two chemicals together, say "cool" and move on. The lab in this curriculum unit is definitely an analytical one. Students will need to do calculations on their data to determine how much they've made.

The general structure of my labs are as such:

- Prelab and Discussion: At the start of a class in which we do a lab, I usually have a few prelab questions that they must answer. Then we discuss the prelab questions and go cover any lab techniques or safety concerns.
- Directions: Students have step by step directions to follow unless the lab is an inquiry lab and then I expect them to come up with their own directions to be approved by me.
- Data: Students should keep a data table of data they've collected in the lab.
- Analysis questions: These are questions that they need to answer based on their data. They usually involve some sort of calculation. For my honors and standard classes, they've not seen how to analyze data from labs like these so they need guiding questions.
- Conclusion: Students are expected to summarize their data and analysis and talk about any errors or what they would do differently.

If the lab is going to be a formal lab, then I use a rubric to grade. If they lab is an informal grade, then I focus in on giving them feedback their calculations and analysis of their data.

Weekly Exit Tickets

Our school's initiative this year are weekly exit tickets to give students feedback about how they are doing with the material in class. As PLCs (professional learning communities), we collaborate with each other on exit tickets based on unpacking the standards for our content area. We discuss with each other what we believe should show mastery for that standard, write questions that show mastery and then come to an agreement on what mastery means and what questions show mastery.

Classroom lessons/activities

Lesson 1: Intro to Moles

Standard: Chm.2.2.5 Analyze quantitatively the composition of a substance.

I can statement:
- I can convert between moles and mass using molar mass
- I can convert between moles and representative particles using avogadro's number
- I can convert from mass to representative particles and representative particles to mass using both molar mass and Avogadro's number.

Essential question: How do I convert between moles, grams and particles?

Assignments: Calcium Supplement Conversions

At the beginning of class, I will have a general a discussion on what dietary supplements are. This is relates our topic to something in the real world as opposed to just looking at amounts of random chemicals. While that has merit, students don't understand why it would be important to them.

I will then go over 2-3 example calculations from data on supplement labels. It would help to have a few different supplements as examples so examples don't need to be pulled from the practice in Appendix 4.

Once students have a grasp on the type of math involved, they will work in their cooperative groups on the "Calcium Supplement Conversions" in Appendix 4. These questions are also supplemented with additional practice with conversions still keeping within the theme of drugs and dietary supplements.

Given that the math involved is a struggle for several students in my classes, I would assign each group in my class a problem to work on a small whiteboard to present to the class. Doing this gets the students invested in being correct. Also, when the presentations occur, the other students in the class need to analyze what their classmates have done and discuss any issues there may be with the work provided. For classes where the confidence in ability is low, instead of presenting in front of everyone, I would have them do a gallery walk and leave post it notes on the other groups work with feedback.

For homework, students will be asked to take pictures of the labels of supplements they have at home and bring that in for analysis the next day. Depending on what they bring in, they could calculate the amount of the active substance that is in a dose of the supplement and compare it to what the label says. This could also generate a discussion on what is safe and what is not safe to take.

Students may at this point have questions on how dietary supplements and drugs differ. This is where it would be good to look over the content research talking about the definition drugs, dietary supplements and cosmetics.

Lesson 2: Using Moles with Formulas

Standard: Chm.2.2.5 Analyze quantitatively the composition of a substance.

I can statement:

- I can calculate percent composition
- I can calculate empirical formulas from percent composition
- I can calculate empirical formulas from masses given
- I can calculate molecular formulas from empirical formulas and a given mass of a molecule.

Essential question: How do you calculate empirical formula?

Assignments: Empirical Formulas with Dietary supplements and Drugs

While I would have liked to focus in on just calcium supplements, I had to broaden the theme to "Empirical Formulas with Dietary Supplements and Drugs." All of the problems within this practice in Appendix 5 have a theme of being about dietary supplements and drugs. Practice problems were taken from Pinto's article[4], Duffy's Website[5] and Bishop's Book.[6]

To introduce the topic, I would go over 2-3 practice problems of calculating empirical and molecular formulas. Then I would give students the practice in "Empirical Formulas with Dietary Supplements and Drugs" to work on in groups.

When groups are done with the practice, they would be assigned them a drug or dietary supplement to research and write their own empirical problem about. They would need to include the following:

- A sentence or two with information about what their chemical is.
- Percent of the elements in their chemical
- A molecular mass
- The following direction: Calculate the empirical and molecular formula of this compound.

Each group would need to check their problem with me. Then groups would exchange problems they designed and answer another group's problem on a whiteboard for presentation to the class. The same procedure for whiteboard presentations would apply in this lesson as in lesson 1 above.

Lesson 3: Stoichiometry

Standard: Chm.2.2.4 Analyze the stoichiometric relationships inherent in a chemical reaction.

I can statement:

- I can write ratios of moles from balanced chemical equations
- I can convert from moles of one compound in a balanced chemical equation to moles of another compound
- I can convert from mass of one compound in a balanced chemical equation to mass of another compound
- I can convert from representative particles of one compound in a balanced chemical equation to representative particles of another compound

Essential question: What is stoichiometry and what do we use it for?

Assignments: Calcium Carbonate Lab

Stoichiometry will be introduced by doing a lab using calcium carbonate. Students will work in six groups to react different calcium carbonate containing items with concentrated hydrochloric acid. The items to be used will be:

- Eggshells
- Chemical grade calcium carbonate
- Tums
- Chalk

Lab directions and analysis questions can be found in Appendix 6.

After each group has answered all the lab questions, we will come together as a class and determine which item contained the most amount of calcium. And probably talk about how even if Tums doesn't have the best percent yield it's probably the safest to take of all of the above substances.

Additional practice with stoichiometry should definitely follow up this lab. This lab should not be the only thing that used to go over stoichiometry but it could be a good introduction or a good ending activity.

Assessments

Weekly Exit Tickets

These weekly exit tickets mentioned in the teaching strategies section will let me know if students are understanding the concepts of stoichiometry during this unit. They will be formative assessments. See Appendix 7 for the weekly exit ticket questions.

Assignments

The assignments given for each lesson will also serve as formative assessments as I look over the students work to see if they understand the material.

Whiteboard Presentations

Seeing how students complete the problems assigned to them on the whiteboard will also let me know how well they understand the material. If there's no answer on a whiteboard that's a pretty clear indication that they are struggling. This would be a formative assessment.

Unit Test

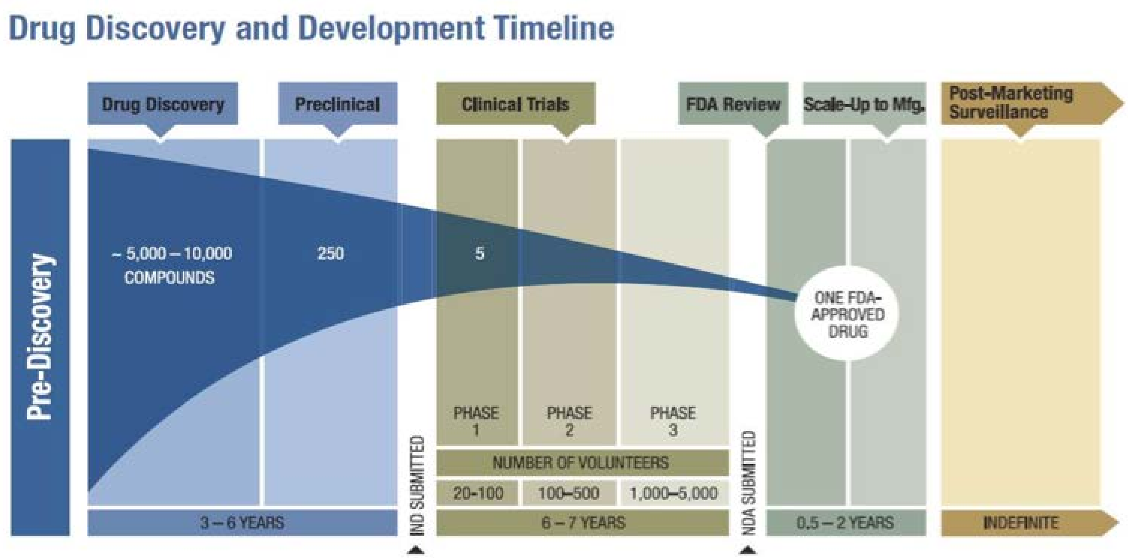
We have a test on the stoichiometry unit so this would this would serve as a summative assessment on how they did in the unit as a whole.

Appendix 1: Teaching Standards

Chm.2.2 Analyze chemical reactions in terms of quantities, product formation, and energy.

- Chm.2.2.1 Explain the energy content of a chemical reaction.
- Chm.2.2.2 Analyze the evidence of chemical change.
- Chm.2.2.3 Analyze the law of conservation of matter and how it applies to various types of chemical equations (synthesis, decomposition, single replacement, double replacement, and combustion).
- Chm.2.2.4 Analyze the stoichiometric relationships inherent in a chemical reaction.
- Chm.2.2.5 Analyze quantitatively the composition of a substance (empirical formula, molecular formula, percent composition, and hydrates)

Appendix 2: Drug Discovery and Development Timeline



Drug Discover and Development Timeline[7]

Appendix 3: Masses of Calcium for Selected Medicines

This table shows the mass of elemental Ca/mg via the manufacturer and via stoichiometric conversions. Consider the "via stoichiometry" column an answer key for Lesson 1.

Medicine	Ca Salt	Mass of elemental Ca/mg	
		via manufacturer	via stoichiometry
A	1250 mg calcium carbonate	500	500.5
B	1260 mg calcium carbonate	500	505
C	1500 mg calcium carbonate	600	601
D	2500 mg calcium carbonate	1000	1001
E	3.3 g calcium phosphate	1.2×10^3	1280
F	A spoonful (=15 mL) of solution with 1671 mg calcium phosphate per 100 mL	100	97
G	A spoonful (=15 mL) of solution with 2088 mg calcium phosphate per 100 mL	125	122
H	A spoonful (=15 mL) of solution with 3088 mg calcium phosphate per 100 mL	180	180
I	3750 mg calcium pidolate	500	508
J	2.94 g calcium lactategluconate and 0.30 g of calcium carbonate	500	500

Appendix 4: Lesson 1

Calcium Supplement Conversions

The following information was taken from manufacturer labels on calcium supplements.

Medicine	Ca Salt	Mass of elemental Ca/mg
		via manufacturer
A	1250 mg calcium carbonate	500
B	1260 mg calcium carbonate	500
C	1500 mg calcium carbonate	600
D	2500 mg calcium carbonate	1000
E	3.3 g calcium phosphate	1.2×10^3
F	A spoonful (=15 mL) of solution with 1671 mg calcium phosphate per 100 mL	100
G	A spoonful (=15 mL) of solution with 2088 mg calcium phosphate per 100 mL	125
H	A spoonful (=15 mL) of solution with 3088 mg calcium phosphate per 100 mL	180
I	3750 mg calcium pidolate	500
J	2.94 g calcium lactategluconate and 0.30 g of calcium carbonate	500

1. For Medicines A-J, calculate via dimensional analysis the amount of calcium in milligrams.
2. Compare your calculated values to the manufacturer values. Are they close? Calculate the percent error for any that are different.
3. If it's recommended that you have 700 mg of calcium a day, how many of each supplement would you need to take to get enough calcium each day? Which supplement do you believe would be the best to buy and take? Why?

4. In the information about a medicine, the manufacturer indicates that there are 800 mg of calcium phosphate, 200 mg of calcium carbonate and 5 mg of calcium fluoride per tablet. According to the information, these quantities are equivalent to 393 mg of Calcium ion and 2.43 mg of fluoride ion. Check these equivalences.

Other Practice Problems

1. A vitamin supplement contains 50 micrograms of the element selenium in each tablet. How many moles of selenium does each tablet contain?
2. A multivitamin tablet contains 1.6 x 10^{-4} mole of iron per tablet. How many milligrams of iron does each tablet contain?
3. Each dose of nighttime cold medicine contains 1000 mg of the analgesic acetaminophen. Acetaminophen, or N-acetyl-p-aminophenol, has the general formula C_8H_9NO.
    a. How many moles of acetaminophen are in each dose?
    b. What is the mass in grams of 15.0 moles of acetaminophen?
4. A common antacid tablet contains 500 mg of calcium carbonate, $CaCO_3$
    a. How many moles of $CaCO_3$ does each tablet contain?
    b. What is the mass in kilograms of 100.0 moles of calcium carbonate?
5. A nutritional supplement contains 0.405 g of $CaCO_3$. The recommended daily value of calcium is 1.000 g Ca.
    a. Write a conversion factor that relates moles of calcium to moles of calcium carbonate.
    b. Calculate the mass in grams of calcium in 0.405 g of $CaCO_3$.
    c. Calculate the mass in grams of calcium in 0.405 g of $CaCO_3$.

Appendix 5: Lesson 2

Empirical Formulas with Dietary supplements and Drugs

Answer the following questions.

1. According to the labels on a medicine recommended for the deficiency of vitamins and mineral salts, each tablet has 90 mg of calcium contains calcium phosphate and 70 mg of phosphate also as calcium phosphate. (They're from the same compound) Note: Sometimes in pharmacology, the term tricalcium phosphate is used for $Ca_3(PO_4)_3$ whereas the term calcium phosphate is reserved for the acid salt of the phosphate, $CaHPO_4$ (called by chemists calcium hydrogen phosphate). Another acid salt exists: $Ca(H_2PO_4)_2$ commonly called calcium dihydrogen phosphate.
    a. Determine which of the salts in the note is the "calcium phosphate" in this medicine.
    b. Calculate the percent composition of each element in each of the three different "calcium phosphates."
    c. Why would there be differences in the naming of these three different ionic compounds? How do they break the rules we've discussed in unit 3?
2. A sample of a compound used to polish dentures and as a nutrient and dietary supplement is analyzed and found to contain 9.2402 g of calcium, 7.2183 g of phosphorus, and 13.0512 g of oxygen. What is the empirical formula for this compound?
3. An ionic compound that contains 10.279% calcium, 65.099% iodine, and 24.622% oxygen is used in deodorants and in mouthwashes. What is the empirical formula for this compound?
4. In 1989 a controversy arose concerning the chemical daminozide, or Alar®, which was sprayed on apple trees to yield redder, firmer, and more shapely apples. Concerns about Alar's safety stemmed from the suspicion that one of its breakdown products, unsymmetrical dimethylhydrazine (UDMH), was carcinogenic. Alar is no longer sold for food uses. UDMH has the empirical formula of CNH_4 and has a molecular mass of 60.099. What is the molecular formula for UDMH?
5. An ionic compound 22.071% manganese, 1.620% hydrogen, 24.887% phosphorus, and 51.422% oxygen is used as a food additive and dietary supplement. What is the empirical formula for this compound? What do you think its chemical name is? (Consider the possibility that this compound contains more than one polyatomic ion.)
6. Thalidomide was used as a tranquilizer and flu medicine for pregnant women in Europe until it was found to cause birth defects. (The horrible effects of this drug played a significant role in the passage of the Kefauver-Harris Amendment to the Food and Drug Act, requiring that drugs be proved safe before they are put on the market.) Thalidomide

is 60.47% carbon, 3.90% hydrogen, 24.78% oxygen, and 10.85% nitrogen and has a molecular mass of 258.23. What is the molecular formula for thalidomide?

7. Vitamin C (MM=176) contains C, H, and O. 4.00 g of vitamin C on combustion gives 6.00 g CO_2 and 1.632 g H_2O. What are the empirical and molecular formulas?
8. A sample of white powder seized by the police was suspected of being cocaine. Combustion analysis of a 0.01832 g sample gave 0.04804 g CO_2 and 0.01099 g of H_2O. The molecular formula of cocaine is $C_{17}H_{21}NO_4$. Can this white powder be the cocaine? Explain your reasoning.

Appendix 6: Lesson 3

Calcium Carbonate Lab

Purpose: To determine the amount of calcium ions that would be freed after the reaction of calcium carbonate with hydrochloric acid.

Prelab:

1. Write the balanced chemical reaction of calcium carbonate and hydrochloric acid?
2. What common household items or dietary supplements have calcium carbonate in them?

Directions:

1. Clean an evaporating dish and record its dry mass with a watch glass on it in the data table.
2. Use a mortar and pestle to grind up your calcium carbonate containing item. Take the mass of your compound in an evaporating dish. Cover with watch glass **curved side down**.
3. Get 8.0 mL of 6 M HCl in a 10 mL graduated cylinder.
4. Using a dropper pipet, slowly add the HCl to the evaporating dish -- a few drops at a time through the small opening between the watch glass and the evaporating dish pour lip. Continue adding acid until the reaction stops. Carefully tilt the evaporating dish back and forth a few times to make sure that the acid has contacted all of the calcium carbonate. remove the watch glass and place it **curved side up** on the lab table.
5. Slowly stir the solution with the dropper pipet
6. Set up a ring stand, ring and wire pad. Place the evaporating dish on the pad and slowly, gently heat the dish.
7. When almost all of the liquid is gone (or when the solution starts to pop out of the evaporating dish, remove the burner and replace the watch glass on the evaporating dish. Heat gently again until no liquid remains on the evaporating dish or the watch glass.
8. Allow the dish to cool
9. Find the combined mass of the watch glass, evaporating dish and product. Record the mass in the data table
10. Rinse your dropper pipet, graduated cylinder, watch glass and evaporating dish. Return the equipment/glasses to their “home”. Why down lab station with a damp paper towel.

Data:

Mass of empty evaporating dish (include the watch glass every time): ___________________________________

Mass of evaporating dish + calcium carbonate: ____

Mass of evaporating dish + calcium chloride: ____

What is the molar mass of calcium carbonate?

How many moles of calcium carbonate are available?

What is the concentration of the acid?

What is the formula for Molarity?

Rearrange the Molarity formula in order to solve for moles.

How many moles of hydrochloric acid are available?

According to the balanced equation, one mole of sodium bicarbonate requires _____ moles of hydrochloric acid.

How does the rate of calcium carbonate consumption compare to the rate of hydrochloric acid use?

Which reactant runs out first (limiting reactant)? (refer to #5, 9, and 11)

Which reactant is not completely used up? (excess reactant)

How many moles of the limiting reactant are used?

How many moles of the excess reactant are used?

How many moles of the excess reactant are left over?

How many grams of the excess reactant are left over-unreacted?

What is the mole ratio between the limiting reactant and calcium chloride product? (use the balance equation coefficients)

Given the moles of limiting reactant used, how many moles of calcium chloride should we expect to be produced?

What is the molar mass of calcium chloride?

Given the moles of calcium chloride expected to be produced (#19), how many grams of calcium chloride should we expect to be produced?

How many grams of calcium chloride were actually produced during the experiment?

What is your % yield?

What is your % error?

How many moles of calcium ions were produced?

Appendix 7: Weekly Exit Tickets

1. **Stoichiometric Mole-to-Mole Conversion**: One disadvantage of burning propane (C_3H_8) is that carbon dioxide (CO_2) is one of the products. The released carbon dioxide increases the growing concentration of CO_2 in the atmosphere. How many moles of carbon dioxide are produced when 10.0 moles of propane are burned in excess oxygen in a gas grill.
2. **Stoichiometric Mole-to-Mass Conversion:** Determine the mass of sodium chloride or table salt (NaCl) produced when 1.25 moles of chlorine gas reacts vigorously with sodium.
3. **Stoichiometric Mass-to-Mass Conversion:** Ammonium nitrate (NH_4NO_3), an important fertilizer, produces N_2O gas and H_2O when it decomposes. Determine the mass of water produced from the decomposition 25.0 g of solid ammonium nitrate
4. **Calculating Percent Composition:** Sodium hydrogen carbonate, also called baking soda, is in active ingredient in some antacids used for the relief of indigestion. Determine the percent composition of sodium hydrogen carbonate ($NaHCO_3$).
5. **Calculating an Empirical Formula from Percent Composition:** Methyl acetate is a solvent commonly used in some paints, inks, and adhesives. Determine the empirical formula for methyl acetate, which has the following chemical analysis: 48.64% carbon, 8.16% hydrogen, and 43.20% oxygen.
6. **Determining a Molecular Formula:** Succinic acid is a substance produced by lichens. Chemical analysis indicates it is composed of 40.68% carbon, 5.08% hydrogen, and 54.24% oxygen and has a molar mass of 118.1 g/mol. Determine the empirical and molecular formulas for succinic acid.
7. **Calculating as Empirical Formula from Mass Data:** Although the mineral ilmenite contains more iron than titanium, the ore is usually mined and processed for titanium, a strong, light, and flexible metal. A sample of ilmenite is found to contain 5.41 g iron, 4.64 g titanium, and 4.65 g oxygen. Determine the empirical formula for ilmenite.

Materials for Classroom Use

Lessons in the Appendix above
Whiteboards for each group in your class
Calcium carbonate containing compounds (see lesson 3)
equipment for lab

- 10 mL graduated cylinder
- evaporating dish
- watch glass
- burner

Hydrochloric acid

Endnotes

1. "Explore 100 Famous Scientist Quotes Pages."
2. "Laws & Regulations - Is It a Cosmetic, a Drug, or Both? (Or Is It Soap?)."
3. "Dietary Supplement Products & Ingredients."
4. Pinto, G. (2005). Stoichiometry of Calcium Medicines.
5. Duffy, Patrick. "Pat's Chemistry Pages." Pat's Chemistry Pages.
6. Bishop, Mark. An introduction to chemistry.
7. Kloda, Shahza Somerville Jessica Holden. "FDA's Expedited Review Process: The Need for Speed."

Annotated Bibliography

Bishop, Mark. An introduction to chemistry. San Francisco: Benjamin Cummings, 2008.
This online textbook has some good practice problems for mole conversions. I will be returning to it for my future planning as the questions are well written have the answers with them.

"Dietary Supplement Products & Ingredients." U S Food and Drug Administration Home Page. Accessed September 21, 2017. https://www.fda.gov/Food/DietarySupplements/ProductsIngredients/default.htm.
This resource discusses the definition of dietary supplements and what they are.

Duffy, Patrick. "Pat's Chemistry Pages." Pat's Chemistry Pages. Accessed October 14, 2017. http://rubious.kwantlen.ca/pduffy/.
This resource has some good practice problems for mole conversions.

"Explore 100 Famous Scientist Quotes Pages." Applied Science Quotes - 28 quotes on Applied Science Science Quotes - Dictionary of Science Quotations and Scientist Quotes. Accessed September 21, 2017. https://todayinsci.com/QuotationsCategories/A_Cat/AppliedScience-Quotations.htm
This resource has some good quotes from famous scientists about applying science versus theoretical science.

Kloda, Shahza Somerville Jessica Holden. "FDA's Expedited Review Process: The Need for Speed." Applied Clinical Trials Home. October 02, 2015. Accessed October 14, 2017. http://www.appliedclinicaltrialsonline.com/fda-s-expedited-review-process-need-speed.
This resource has a good image that summarizes the drug discovery process.

"Laws & Regulations - Is It a Cosmetic, a Drug, or Both? (Or Is It Soap?)." U S Food and Drug Administration Home Page. July 8, 2002. Accessed September 21, 2017. https://www.fda.gov/Cosmetics/GuidanceRegulation/LawsRegulations/ucm074201.htm?_sm_au_=iVVqqvrdZ0fBs0NV.
This resource discusses the definition of what a cosmetic and what a drug is.

Pinto, G. (2005). Stoichiometry of Calcium Medicines. *Journal of Chemical Education,82*(10), 1509. doi:10.1021/ed082p1509

This resource has good information on using calcium supplements for stoichiometry practice.

Pinto, G. (2009). Fluorine Compounds and Dental Health: Applications of General Chemistry Topics. *Journal of Chemical Education,86*(2), 185. doi:10.1021/ed086p185

This resource has good information on using fluoride supplements for stoichiometry practice.

Umland, J. B. (1984). A recipe for teaching stoichiometry. *Journal of Chemical Education,61*(12), 1036. doi:10.1021/ed061p1036

This resource uses recipes to teach stoichiometry.