New Tutorial Programs for Gateway General Chemistry Courses at Syracuse University is being Developed

This project has been launched on May 2006… More to come…

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…..The team is currently working on materials and hand-outs that contain <u>*reviews, example questions, surveys, and assignment questions*</u> that will help students with math-related chemical problems. The materials will be ready for Spring 2007 and they will be tested for the first time in CHE 116 class in Spring 2007. Professor Asefa will be teaching this course in Spring 2007. Further modifications will follow thereafter.

Works currently in progress include on topics such as (the draft handout is available below) and it consists of

1) Numbers, exponential notations, and significant figures
2) Logarithms
3) Unit conversions
4) Stoichiometry (math-oriented)
5) Reaction rates,
6) etc.

More to come…..

Introduction

My prior experience teaching Introduction to Chemistry for Non-Majors and General Chemistry Laboratory for Science Majors at Syracuse University, combined with courses I have taught over the past ten years have provided me with two points: (1) a significant number of students (both science and non-science majors) lack critical fundamental math skills essential for the successful completion and/or mastery of gateway or entry-level

Chemistry courses; and (2) educational approaches used inside or outside the classroom must be appropriate to the intellectual and personal development of the learner.

To address these observations, I have initiated an educational program/initiative to develop a new intensive tutoring program on math-related topics for implementation in gateway courses by working with the Division of Tutoring and Retention at Syracuse University and Department of Science Education. This educational program/project is designed to (1) assess the impact of supplemental support in key mathematical concepts on class drop-out rates in first-year gateway courses; and to (2) modify my educational approaches to meet the needs of diverse learners, and by doing so, increase interest in science as well as the learner's appreciation of the relevance of science to their everyday lives and in society.

Background

In Fall 2005, I first taught Chemistry in the Modern World (Introduction to Chemistry) to 75 non-major students with diverse backgrounds and little or no prior knowledge of chemistry. The course was designed to give general scientific knowledge to students regarding air pollutants, energy, plastics, drugs, etc. I used "Chemistry in Context", 5th edition, McGraw Hill. The student's mastery of course content was assessed by four multiple-choice examinations; on the final examination, I also included four written questions to assess how the students perceived the course in general, how they understood the topics and how they could relate topics with one another. Statistical analysis of exam results and insights gleaned from class discussions revealed that understanding chemical principles involving mathematical concepts (e.g., conversion of units and mathematical calculations on the interaction of matter with electromagnetic radiations) were particularly challenging for students presumably weak in math skills. In addition, many non-science majors seemed to lack any interest in science, despite my concerted efforts to make the material relevant and exciting. Available institutional data indicate that over the past few years, significant number of students, on average, originally enrolled in the course drop out prior to completion and many received a C or below.

General Chemistry laboratory, the companion to General Chemistry lecture for science majors enrolls about 400 students and is designed to help students learn experimental techniques and understand chemical principles related to their lecture. In most experiments, students are required to prepare chemical compounds and analyze their properties, study reactions between substances, make various measurements, and complete qualitative and quantitative analysis of unknown samples. They are also required to create plots, conduct data analysis and relate experimental results with chemical principles learned in lectures. Although students enrolled in this course are exclusively science majors with strong interest in the course material, even here, a significant number have difficulty in understanding those chemical problems that involve common mathematical analysis and conversions. The drop out rate for this course was about 9%.

Intensive tutoring program on math-related topics to increase retention and performance in Chemistry gateways courses for majors and non-majors

Both Chemistry in the Modern World ((Introduction to Chemistry for Non-Majors) and General Chemistry laboratory historically have been taught in a rather traditional fashion (i.e., lecture format). Neither of these courses has a recitation, although students in the lab class may have access to recitations via General Chemistry lecture. For my two courses, I will develop and implement a supplemental support program, Peer Led Team Learning (PLTL), new to Syracuse University. I will also make concerted efforts to develop course content that is delivered in an exciting and engaging manner. These strategies are designed to address the challenges students face in solving chemical problems involving math as well as to increase interest in and appreciation of science and its relevance to their everyday lives and society.

To facilitate PLTL, I will work with Ms. Jane Neuburger, Director of Syracuse University's Tutoring and Study Center in the Division of Student Support and Retention and Prof. Sharon Dotger, Department of Science Education. The PLTL strategy, developed under the NSF's systemic change initiative in the 1990s, was developed to create a more peer student-centered learning environment for students.[1] With Ms. Neuburger's assistance, I will adapt this program for students in these gateway courses, starting with Chemistry in the Modern World and General Chemistry lab, and then including General Chemistry lecture, which I will teach in Spring 2007. Students in need or risk of drop out will be identified using an assessment aid that will be given to all students at the beginning of the course. Similar assessment aid is being developed by Prof. Mark Braiman and is currently under consideration for use by the entire department. This combination of multiple choice and fill-in the answer assessment tool has a set of 20 questions on topics that should be covered in high-school. From students who perform poorly in mathematical skills by the assessment test as indicated by a score of 5 or below out of 20 (average score is 12), 10 students will be randomly chosen from introductory chemistry and 20 students from Chemistry lab. These students will be invited to join small groups of five led by a peer leader who has successfully completed the course in the previous year(s). This kind of learning strategy has been reported to be effective and fun for the students supported as well as for the peer leader.[2]

The peer leader will lead each group and he/she will have regular meeting with me twice a week to review and report potential obstacles that may appear and discuss possible solutions. The peer leader and the students will also meet twice a week for 1 hr each in TA-Rooms in our department that has that has white boards and round tables. The peer-leader to student meetings will involve both round-table discussion and the use of white boards. The peer leader will first look into the hand-outs I will prepare with me before his/her meetings with students and then distribute the hand-outs, explain thoroughly the information in them and lead the questions and discussion with the students. Importantly, the peer leader will also play role model for the students. In the program, I will choose topics from General Chemistry text books by Nivaldo Tro, Prentice Hall, 2nd Ed. and Ebbing, Houghton Mifflin, 8rd Ed. that have much mathematical related chemical problems. I will include these in hand-outs to give reviews on a few common chemical principles, supplementary information about mathematical formulas and equations commonly used in chemistry. These will include units and their conversions, exponential notations, stoichiometry, etc. I will also prepare and give instruction to the peer leaders to guide them through. Furthermore, weekly assignments on the mathematical problems will be given to students and they will be corrected and discussed with the peer leader. To encourage peer participation in this program, in addition to modest compensation which I will request from the Department, I will explore the feasibility of obtaining University community service certificates through the Center for Community and Public Service to acknowledge their service.

During the first year of the program, formative assessments via monthly surveys will be made with the assistance of the Office of the Center for Support of Teaching and Learning to learn students' perceptions on the various topics and identify areas where the process might be modified. Their progress will also be evaluated with their assignment results. Finally, data collection and analysis will be conducted at the end of the semester using methods reported previously.[3] These will typically contain data regarding total points earned on each exam, final course grades, gender, and race/ethnicity; survey results used to capture the perceptions and opinions of the students about the program; and informal and formal interviews with the students and peer leaders. As I repeat the PTLT annually, I will modify its implementation based on assessments from the prior year to improve its effectiveness. Over time, I will accumulate information on the program's impact on retention, allowing me to informally assess its impact.

Indicators of programmatic success for these approaches include: percent of students who drop out is reduced over time, and improved exam performance (particularly in math-related problems), and increased interest in science in general and the courses in particular. I also plan to publish the outcomes of these results on the Journal of Chemical Education.

References:

1. Burke, K. A.; Greenbowe, T. J.; Lewis, E. L.; Peace, G. E. "The Multi-initiative dissemination project: Active learning strategies for college chemistry" *J. Chem. Ed*. **2002**, *79*, 699.

2. Lewlis, S. E.; Lewis, J. E. "Departing from lectures: An evaluation of a peer-led guided inquiry alternative" *J. Chem. Ed*. **2005**, *82*, 135-139.

3. Lyle, K. S.; Robinson, W. R. "A statistical evaluation: Peer-led team learning in an organic chemistry course" *J. Chem. Ed*. **2003**, *80*, 132-134.

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Hand-Outs for PLTL Math-based Chemistry Tutorial:

The final phase of the handout preparation is now in progress. These handouts will be edited, printed, bound and given to students, peer tutors, and graduate students and assistants that are participating in our Peer-Led Team learning (PLTL) Tutorial programs.

LESSON 1

This lesson will comprise of 3 subjects

1. Significant figures
2. Exponents
3. Scientific Notation

Significant Figures - the meaningful digits in a measured or calculated quantity

To take into account inaccuracies in measurements and calculations, chemists round up numbers.

There are **4** rules to remember to help you out:

1. Any digit that is not zero, **is** significant.

423 meters(m)= 3 significant figures

5**.**2 centimeters(cm)=2 significant figures

45**.**37 milliliters(mm)=? Significant figures

305 grams(g)=? Significant figures (SEE NEXT RULE)

2. Zeros between nonzero digits **are** significant.

505 milligrams(mg)=3 significant figures

3**.**01 joules(J)= 3 Significant figures

32**.**4503 centimeters (cm)=? Significant figures

0**.**015 Liters (l)=? Significant Figures(SEE NEXT RULE)

3. Zeros to the left of the first nonzero digit are **not** significant.

0**.**0032 meters (m)= **2** significant figures(the zeros to the right of the decimal are **not** significant)

0**.**0178 kilometers (km)=**3** significant figures

0**.**000987 kilograms (kg)=? Significant figures

3**.**0450 kilojoules(kJ)=? Significant figures(SEE NEXT RULE)

4. If a number is greater that 1, then **all** the zeros written to the right of the decimal **are** significant

2**.**0580 grams (g)=**5** significant figures(the last zero counts)

0**.**0490 meters (m)=**3** significant figures (the last zero counts, the zero following the decimal point does **NOT**)

0**.**90140 liters (l)=? Significant figures

Exponents - Instead of dealing with very large numbers, it is easier to simplify them

When you see 10^3 it signifies 10 x 10 x 10=1000
The exponent represents how many 10's
are multiplied

SO: instead of 900000000**.** x 7000000**.**

You can simplify by just multiplying by 10, to the exponent of the number of times you move the decimal

9**.** x 10^8 x 7**.** x 10^6

Begin with $10^?$, and count the number of times the decimal point must move to have one non-zero number in front of it

783456000 =

8974 =

173921 =

Working with the original example, what would the answer be (without a calculator)?

There are rules when dividing and multiplying numbers with exponents, and they are easy to remember:

When DIVIDING, SUBTRACT the exponents

When MULTIPLYING, ADD the exponents

$$10^5/10^3=10^{(5-3)}=10^2$$

$$10^5 \text{ x } 10^3=10^{(5+3)}=10^8$$

If there are numbers before the 10, just multiply or divide them

$(8 \text{ x } 10^4) \text{ x } (4 \text{ x } 10^2) = (8 \text{ x } 4) \text{ x } (10^{(4 + 2)})= 24 \text{ x } 10^6$

But $(8 \text{ x } 10^4) / (4 \text{ x } 10^2) = (8/4) \text{ x } (10^{(4 - 2)}) = 2 \text{ x } 10^2$

$10^6/10^3=$
$(6 \text{ x } 10^6) / (3 \text{ x } 10^4) =$
$10^7 \text{ x } 10^{12} =$
$(12 \text{ x } 10^5) \text{ x } (4 \text{ x } 10^7) =$

Scientific Notation - An easy way to write very large numbers or very small numbers

The key to Scientific Notation is counting the number of times to move the decimal place, so that only one number (other than zero) is before the decimal point. The exponent will be positive.

Example to write the number 321903465**.** in scientific notation, just move the decimal point to the left 8 times

$$321903465. = 3.21903465 \times 10^8$$

$$65400. = 6.54 \times 10^4$$

NOTE Do not add the zeros before the decimal point, they are just place holders

Begin with $10^?$, and count the number of times the decimal point must move to have one non-zero number in front of it

89762458 = ?

7865 = ?

980 = ?

This also works for very small numbers, just count the number of times you must move the decimal point to the right, just remember to make the exponent on the 10 <u>negative.</u>

Example:

$$0.00000090780 = 9.0780 \times 10^{-7}$$

NOTE You must add the zero after numbers if you are to the right of the decimal point

Begin with $10^{-?}$, and count the number of times the decimal point must move to have one non-zero number in front of it

0.0065800=

0.078=

0.00000471=

Review: Converting between moles, molecules and grams

Avogadro's Number = 6.022×10^{23} molecules/mol   Atomic mass = grams/mol   Molecular mass = gm/mol

That means
- A mol of molecules contains 6.022×10^{23} molecules
- A mol of a substance contains its atomic mass in grams
- A mol of a substance contains its atomic mass in grams

How many molecules are in 12 grams of Helium??

First step is to figure out what you have, and what you need
HAVE: 12 **grams** He   Need: **molecules** He

And realize you must convert from grams to mol first, then from mol to molecules

NOTE Look at periodic table to determine atomic mass (the number under the He=4.0026, 4 is close enough

Second Step, make first conversion from grams to mol

$$12 \text{ grams He} \times \frac{1 \text{mol He}}{4 \text{ grams}} = 3 \text{ mol He}$$

(Flip the atomic mass, to that grams cancel out)

Third step, make second conversion from mol to molecules

$$3 \text{ mol He} \times \frac{6.022 \times 10^{23} \text{ molecules}}{\text{mole}} = 18.066 \times 10^{23} \text{ molecules}$$

In 12 grams of He, there are 1.8066×10^{24} molecules

Now try the following conversions for yourself:

1. 28 grams Nitrogen to molecules Nitrogen

2. 3.011×10^{23} molecules Carbon to grams Carbon

3. 69 grams Sodium (Na) to moles Sodium

4. 4 mol Sulfur to molecules Sulfur

LESSON 2

This lesson will comprise of 2 subjects

1. Unit Conversions
2. Logarithms and natural logarithms

Unit Conversions - Throughout chemistry it will become necessary to convert the unit without changing the value

Unit Conversions will also help you solve problems, as will be explained in later lessons

The metric system is set up in multiples of 10, so all you need to do is remember the prefixes

PREFIX	Abbreviation	Meaning	Example
Giga	G	10^9	1 gigameter (Gm)= 1 x 10^9
Mega	M	10^6	1 megameter (Mm)= 1 x 10^6
Kilo	k	10^3	1 kilometer (km)= 1000 m
Deci	d	10^{-1}	1 decimeter (dm)= 0.1 m
Centi	c	10^{-2}	1 centimeter (cm)=0.01 m
Milli	m	10^{-3}	1 millimeter (mm) = .001 m
Micro	μ	10^{-6}	1 micrometer (μm)= 1 x 10^{-6}
Nano	n	10^{-9}	1 nanometer (nm) = 1 x 10^{-9}

The base units of measure for the metric system are as follows

Physical Quantity	Name of Unit	Abbreviation
Mass	gram	g
Length	meter	m
Time	Second	s
Electrical Current	Ampere	A
Amount of Substance	mole	mol
Volume	liter	L

Practice with the Following Conversions - first find the correct factor from the previous page (kilo, milli, etc.) and use the factor to convert

Note This is easier if you use fractions as conversion factors like the first example, this will help you IMMENSELY in the Future, just make sure whatever you are initially given is on the bottom of the equation so it can be cancelled

3.5 L X $\frac{10^3 \text{ mL}}{1\text{L}}$ = 3,500 mL

2.84 kg X _______ = ______ g

498 mm X _______=________ m

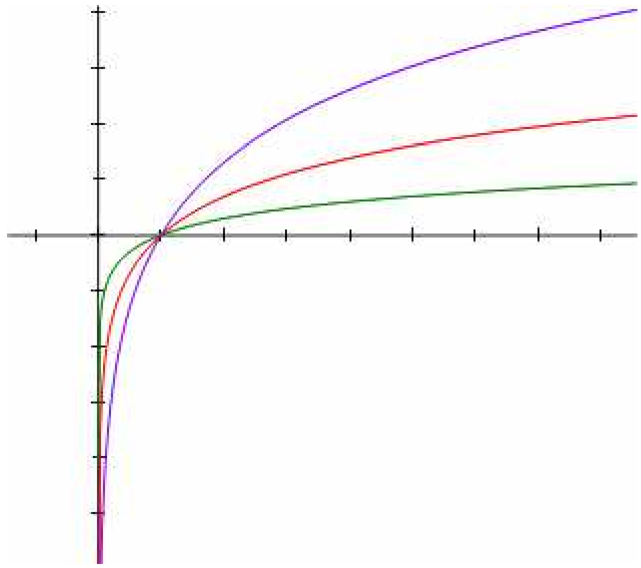
2.1 L X _____= ______ µL

756mA X _____=_____ A

1.7 mol X _____=

3245 mm X______=_______ **km**, you can use one conversion factor, but you can also do the calculation twice (mm→m   m→km)

<u>Logarithms</u>- A way of representing large numbers, is especially useful for creating straight lines, which will become more important later on, so understand logarithms now!!



Logarithms to various bases: red is to base *e*, green is to base 10, and purple is to base 1.7. Each tick on the axis is one unit. Note how logarithms of all bases pass through the point (1, 0). (This is so because any (nonzero) number raised to the power 0 is 1.)

From Wikipedia.org

The logarithm of a number *x* is base *b* to the power *n* $x = b^n$

So $100 = 10^2$

Where 100 = x 10 = b n = 2(the power)

The other way to express $x=b^n$ is:

$\text{Log}_b(x) = n$

Where the same numbers correspond 100 = x 10 = b n = 2

$\text{Log}_{10}(100) = 2$

note If you just see Log 4, this means $\text{Log}_{10}\,4$, or $10^4 = 10{,}000$, you should just be able to use your calculator by hitting the "log" key and then the #, make sure you can use your calculator by checking to make sure log100 = 2.

SOLVE THE FOLLOWING LOGARITHM PROBLEMS

1. $\log_{10} 4$=??
2. $\log_{10} 5.78$=??
3. $\log_{10}$??=3.45 (hint convert to $x=b^n$)
4. log ??=4.378
5. $\log_e 100$=?? (If this is confusing, move on to the next section)

REMEMBER SIGNIFICANT FIGURES, it is a silly reason to lose points it!

NOW JUST LIKE THE PREVIOUS PROBLEMS, SOLVE THESE ln PROBLEMS

1. ln 4=??
2. ln 5.78=??
3. ln ??=3.45 (hint convert to $x=b^n$, this still works with ln, just make the base (b)=e)
4. ln??=4.378
5. $\log_e 100$=?? (I hope you can solve this now)

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#1 When taking the logarithm of two multiplied variables, you can split it up and add them

Logarithmic Rule #2 $\text{Log}_a\left(\frac{x}{y}\right) = \text{Log}_a(x) - \text{Log}_a(y)$

#2 When taking the logarithm of two divided variables, you can split it up and subtract them

Logarithmic Rule #3 $\text{Log}_a(x)^y = y\text{Log}(x)$

#3 When your logarithm is raised to a power, you can move the power to the front of the equation and multiply

LESSON 3

This lesson will comprise of 3 subjects

1. Solving two equations with two unknowns
2. Reaction Rates
3. Determining orders of reactions

1. Solving two equations with two unknowns

$x + y = 10$ $y - x = 4$ $x = ?$ $y = ?$

Can you solve for x and y with these two equations? If not follow these simple steps

1. Make sure you have as many equations as you have variables (here we have two equations, and two unknowns, x and y)

2. Solve one of the equations, so that a variable is by itself on one side (for the first equation $(x + y) - y = 10 - y$ subtract y from each side
   $x = 10 - y$

3. Now plug the variable you just solved for (x) into the other equation, which is $y - x = 4$

$x = 10 - y$ $y - (10 - y) = 4$ Remember to distribute the minus sign

4. Solve the equation just formed

$y - (10 - y) = 4 \rightarrow y - 10 + y = 4 \rightarrow 2y - 10 = 4 \rightarrow 2y = 14 \rightarrow \mathbf{y = 7}$

5. Now plug the value into one of the original equations, and solve for the other variable

$\mathbf{y = 7}$ $x + y = 10 \rightarrow x + 7 = 10 \rightarrow \mathbf{x = 3}$

You can check it, by placing the y into the second equation

$\mathbf{y = 7}$ $y - x = 4 \rightarrow 7 - x = 4 \rightarrow 7 = 4 + x \rightarrow \mathbf{3 = x}$ √

Now here are some examples, just follow the 5 steps

NOTE This can be done for multiplication and division, no problem

$A+B=12 \quad A-B=7$	$\frac{X}{Y}=5 \quad X-Y=12$
$XY=10 \quad X+Y=7$	$XY=18 \quad \frac{X}{Y}=3$

2. Reaction Rates

This section is about how different chemicals react with each other, and how their concentrations over time change. The reaction rate measures the change in concentration of the reactants over time, the values here will ALWAYS be over time, hence the word rate, like

$$\frac{\text{miles}}{\text{hour}} \quad \text{or} \quad \frac{\text{feet}}{\text{second}} \quad \text{or} \quad \frac{\text{gram}}{\text{second}}$$

So with this equation $2H^+ + O_2 \rightarrow H_2O$ you get water when you add two hydrogen ions and an oxygen molecule

BUT this doesn't happen in an instant, the concentration of hydrogen and oxygen decrease over time, until all (or nearly all of) the hydrogen and oxygen are converted to the water.

This is similar when one compound decomposes to form two separate molecules LIKE:

$$2NO_2 \rightarrow 2NO + O_2$$

The nitrogen dioxide(NO_2) decomposes to nitrogen oxide(NO) and oxygen (O_2)

Note decomposes just means “breaks-down” or “fragments” which reduces concentration the original material over time, similar to soda being left out, which loses carbonation over time

BUT: How fast does the nitrogen dioxide decomposes?? Here are some values to solve this

Drew: Should we talk a bit on concetrations and concentration units before the question below?

GIVEN: At the beginning of an experiment (time zero seconds (0s)) the concentration of nitrogen dioxide in a vessel is 0.2203 mol/L. After 60 seconds, the concentration decreased to 0.1076 mol/L.

SO the question is---What is the average rate of decomposition of NO_2 during this time?

Hint the answer must be in mol/(L*s)---This is a hint, and when things get more difficult, sometimes you can get the right answer just by knowing what units the answer has to be in!!

Since this is a rate, and I told you the answer had to be in mol/(L*s), the change of amount will have to be divided by the total time

So at time 0 s there was 0.1103 mol/L and at time 60 s there was 0.1076 mol/L

$$\frac{(0.1103\text{mol/L} - 0.1076\text{ mol/L})}{(0\text{ s} - 60\text{ s})}$$

$$\frac{0.0027\text{ mol/L}}{-60\text{ s}}$$

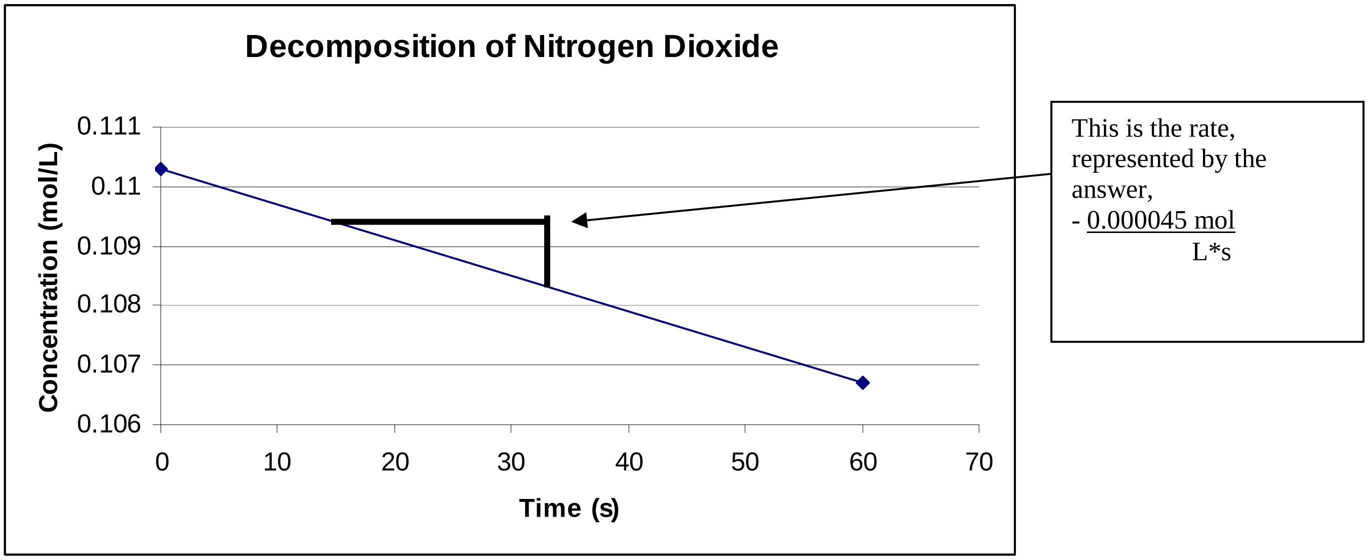
This negative sign is good, because this is a decomposition reaction NO_2 is being reduced

$$-\frac{0.000045\text{ mol/L}}{\text{s}} = -\frac{0.000045\text{ mol}}{\text{L*s}}$$

SO the nitrogen dioxide is being degraded or “fragments” at a rate of $\frac{0.000045\text{ mol}}{\text{L*s}}$

Or: In physical sense, 0.000045 mol of nitrogen dioxide fragments or degrades from within a liter of solution in a second time.

Drew: it is also good to have this in exponential notations, isn't it? Like 4.5×10^5 mol/L.s



Here is one example to practice

Azomethane, $CH_3NNCH_3 \rightarrow C_2H_6 + N_2$
The initial concentration of azomethane was 0.015 mol/L. After 420 seconds, this concentration decreased to 0.0101 mol/L.

Find the reaction rate in mol/(L*s)

Review:
Rate = k[reactant1]^m [reactant2]^n…   The exponents m and n signify orders of the reactions

Zero order = if changing reactant concentration has no effect on rate

First order = if as reactant concentration changes the rate changes proportionately (double the concentration doubles the rate)

Second order = if doubling the concentration increases the rate by 4 or ($2^2 = 4$), tripling the concentration will increase the rate by 9 (3^2=9), so rate will change exponentially with concentration change

Effect on Rate of Doubling the Initial Concentration of Reactant	
order	**Rate is Multiplied by:**
0	**1**
1	**2**
2	**4**

So how do you tell what order a reaction is?? Consider the following

The following data was measured for the reaction $2NO + O_2 \rightarrow 2NO_2$

Experiment	**[NO] (M)**	**[O_2] (M)**	**Initial Rate (M/s)**
1	0.0162	0.0125	0.0141
2	0.0252	0.025	0.113
3	0.0252	0.0125	0.0564

NOTE before continuing, capital M means molarity, moles/L; square brackets [ ] around something signifies concentration, in this case M (mol/L) where m/L is moles per liter and is a unit of molarity.

$$\text{Rate} = k[NO]^{?}[O_2]^{?}$$

$$K = \frac{\text{Rate}}{[NO]^{?}[O_2]^{?}}$$

To determine the change in rate constant, choose two different experiments where one of the reactants remains the **same**, while the other **changes**, like experiment 1 and experiment 3 in the table above; i.e.

Experiment	[NO] (M)	$[O_2]$ (M)	Initial Rate (M/s)
1	0.0162	0.0125	0.0141
3	0.0252	0.0125	0.0564

In this case the O_2 concentration remains the same, the NO concentration doubles, and the rate quadruples (i.e. 0.0141 X 4 = 0.0564)

So as [NO] doubles, rate quadruples ($2^2 = 4$) this means the reaction is second order with respect (consult chart above) to NO

NOW to determine the order of O_2, first pick two experiments where NO stays the **same** and O_2 **changes**

Experiment	[NO] (M)	$[O_2]$ (M)	Initial Rate (M/s)
2	0.0252	0.025	0.113
3	0.0252	0.0125	0.0564

Between experiment 3 and experiment 2 concentration of O_2 doubles while NO concentration remains the same, and the rate doubles (0.0564 X 2 = 0.113)

** Note** Choose experiment order that will give you positive numbers, instead of going experiment 2 to 3, which would have been reducing by half, go from experiment 3 to 2 where you have to double, it will make things easier and less confusing

So as $[O_2]$ doubles, rate doubles ($2^1 = 2$) this means the reaction is first order with respect to O_2

$$\text{Rate}=k[NO]^?[O_2]^? \quad \text{Is now found to be} \quad \text{Rate}=k[NO]^2[O_2]^1$$

Now that that is solved, the next question is what is the average rate constant, k?

$$K = \frac{\text{Rate}}{[NO]^2[O_2]^1}$$

For experiment 1, $k_1 = \dfrac{0.0141\ (M/s)}{[0.0126\ M]^2[0.0125\ M]^1} = \dfrac{0.0141\ (M/s)}{0.000262\ M^2 \times 0.0125\ M}$

$$k_1 = \frac{0.0141}{0.00000328\ M^2 s} \qquad k_1 = \frac{7105}{M^2 s}$$

For experiment 2, $k_2 = \dfrac{0.113(M/s)}{[0.0252\ M]^2[0.0250\ M]^1}$

$$k_2 = \frac{7118}{M^2 s}$$

For experiment 3, $k_3 = \dfrac{0.0564(M/s)}{[0.0252\ M]^2[0.0125\ M]^1}$

$$k_3 = \frac{7105}{M^2 s}$$

Average k = $\dfrac{k_1+k_2+k_3}{3} = \dfrac{(7105+7118+7105)}{3}$

Average value of the rate constant k = $\mathbf{\dfrac{7109}{M^2 s}}$

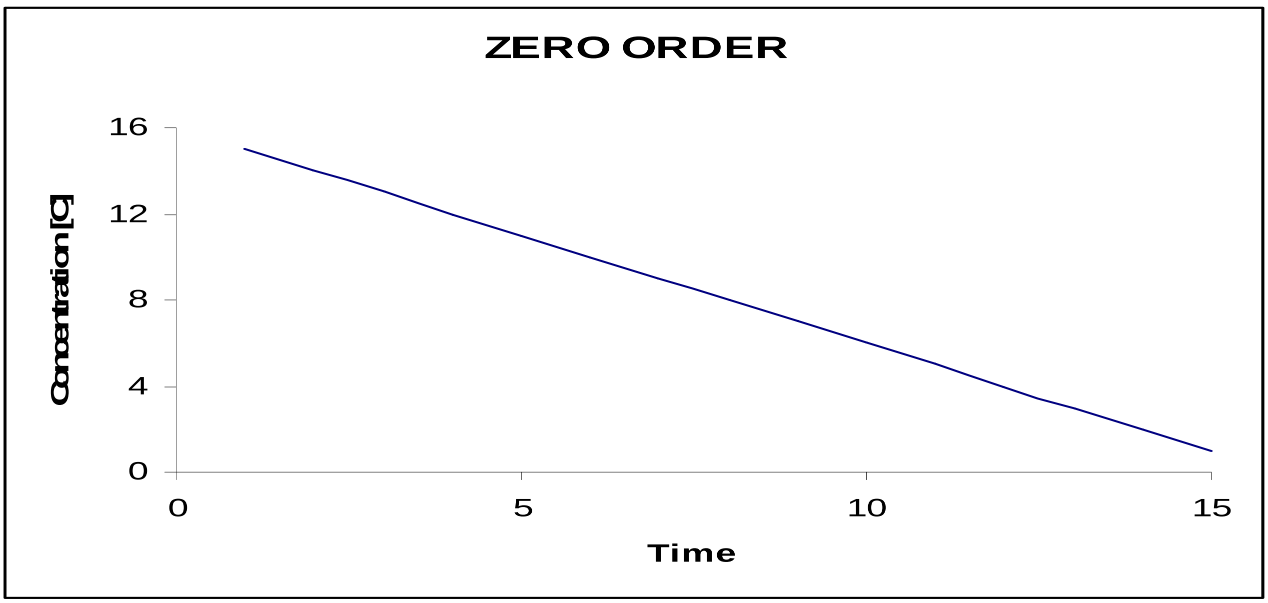
This takes along time, but if you go step by step you should be fine, all problems dealing with this are just variations on this theme, to help you practice here is an example:

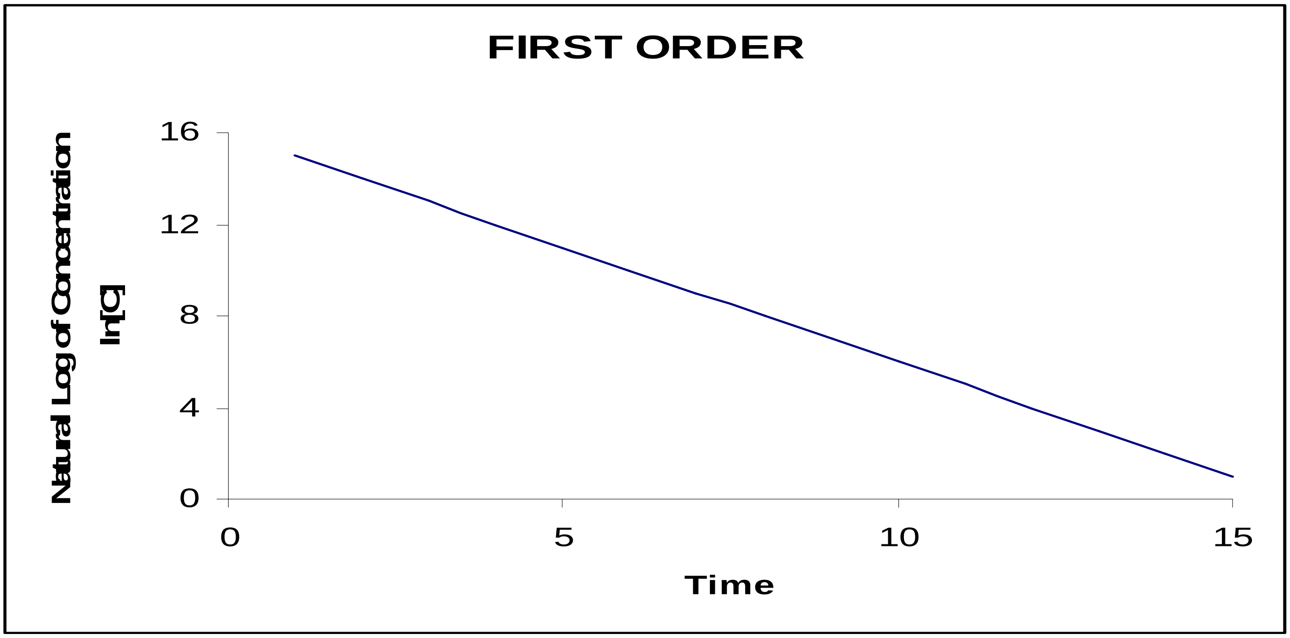
The following data was measured for the reaction $BF_3 + NH_3 \rightarrow F_3BNH_3$

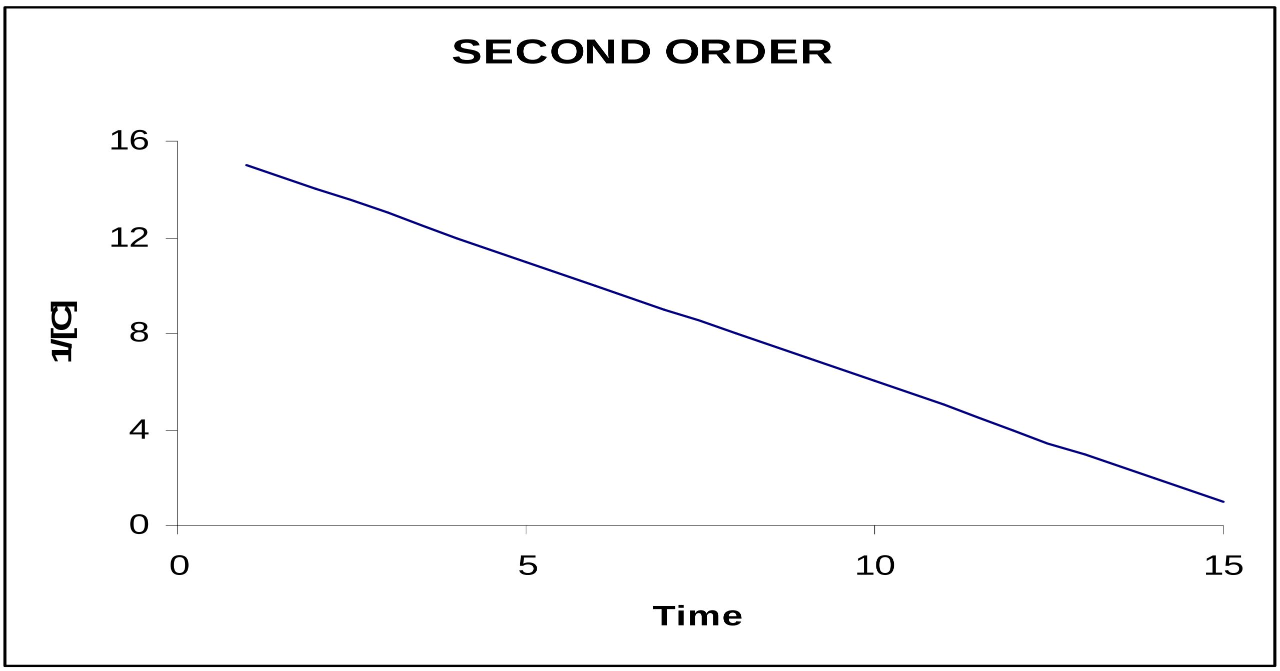
Experiment	$[BF_3]$ (M)	$[NH_3]$ (M)	Initial Rate (M/s)
1	0.25	0.25	0.213
2	0.25	0.125	0.1065
3	0.2	0.1	0.0682
4	0.35	0.1	0.1193

a) determine order of the reaction for BF_3 and NH_3
b) determine the average value of the rate constant

The orders of reaction are displayed below, you can notice that all of them are straight lines, but the scale on the y-axis changes. To determine what order the reaction is from data, just plot the data with the corresponding scales and see which one is a straight line. An example of this follows the graphs:







NOTE Have you ever heard of half life? Half life is the length of time it takes for the concentration of a substance be cut in half; i.e. (from 100 mg/L to 50 mg/L) and is nearly always first order. This is how things are carbon-dated, scientists measure the amount of Carbon 14, which has a half life of 5730 years to determine how old something is.

Chernobyl (the site of a nuclear power plant failure) occurred in 1986 and is not yet inhabitable since the half lives of two radioactive isotopes released (Strontium 90 and Cesium 137) are about 30 years. It will take about 3 half lives for the area to be "safe" again, in 90 years the radioactive level will be 12.5 % of the original concentration. (100%→ 50% 50%→25% 25%→12.5% - in 30 years each and 90 years overall)

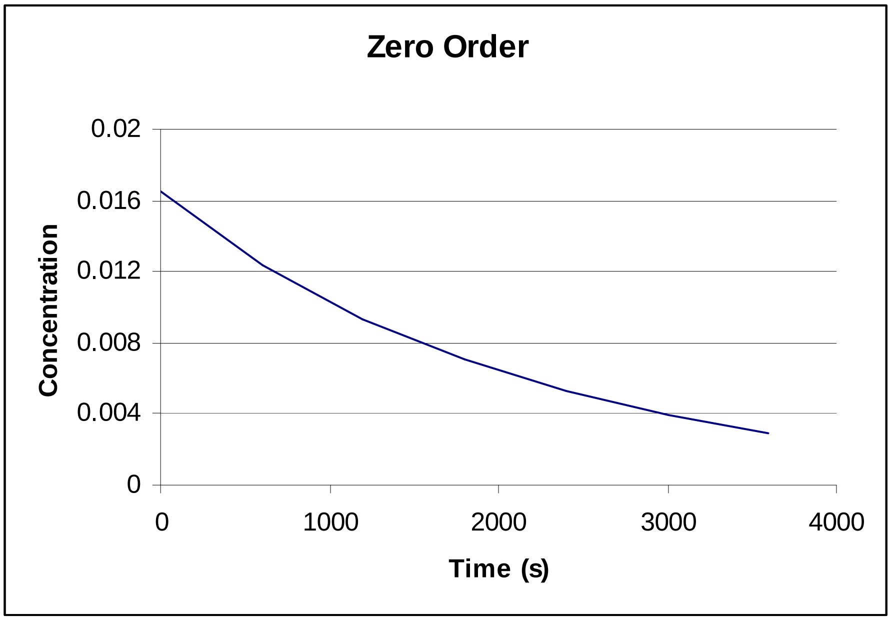
EXAMPLE OF RADIOACTIVE DECAY???
CHART ON p. 580???

EXAMPLE: The following data set is given:

Time	$[N_2O_5]$
0	0.0165
600	0.0124
1200	0.0093
1800	0.0071
2400	0.0053
3000	0.0039
3600	0.0029

What is the order of the reaction??

First STEP: To see if the data is Zero order, graph Concentration on the y axis vs time on the x axis and get:



This is not a straight line, so the reaction is not zero order.

Second STEP: To see if the data is First order, graph the natural log of Concentration on the y axis vs time on the x axis and get:

Time	$[N_2O_5]$	ln $[N_2O_5]$
0	0.0165	-4.10439
600	0.0124	-4.39006
1200	0.0093	-4.67774
1800	0.0071	-4.94766
2400	0.0053	-5.24005
3000	0.0039	-5.54678
3600	0.0029	-5.84304
X AXIS		Y AXIS

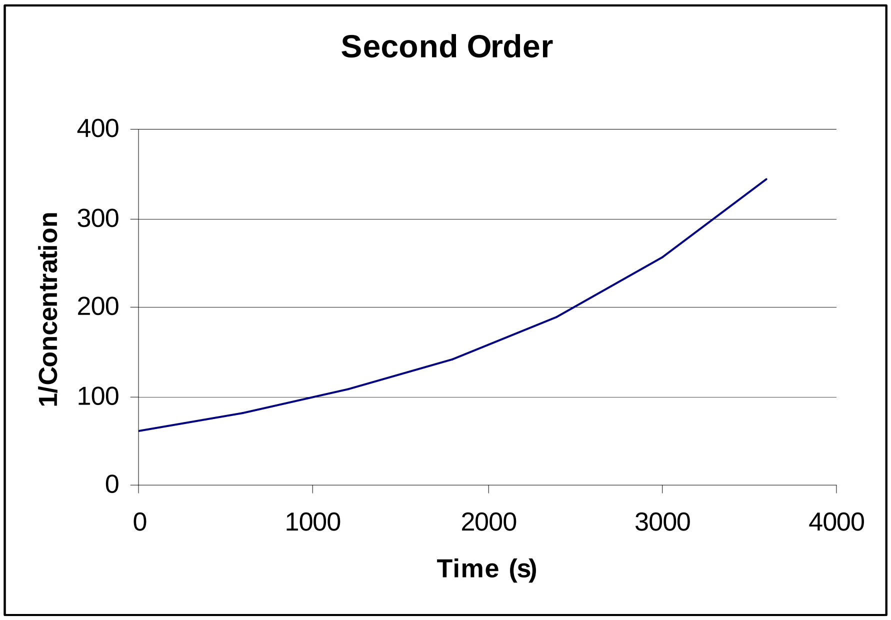
This is a straight line so the reaction **is** first order. The negative numbers on the graph are a little confusing, Drew! Is there another way of plotting it?

If it had not been a straight line, you must take a third step and determine if the data is second order.

Third STEP: To see if the data is Second order, graph 1 over Concentration on the y axis vs time on the x axis and get:

Time	[N_2O_5]	1/[N_2O_5]
0	0.0165	60.60606
600	0.0124	80.64516
1200	0.0093	107.5269
1800	0.0071	140.8451
2400	0.0053	188.6792
3000	0.0039	256.4103
3600	0.0029	344.8276

X AXIS   Y AXIS



This is **not** a straight line, confirming that the reaction is **not** second order and **is** first order.

EXAMPLE: Given the following data set, what order is the reaction?
You must graph all orders, to determine what creates a straight line!

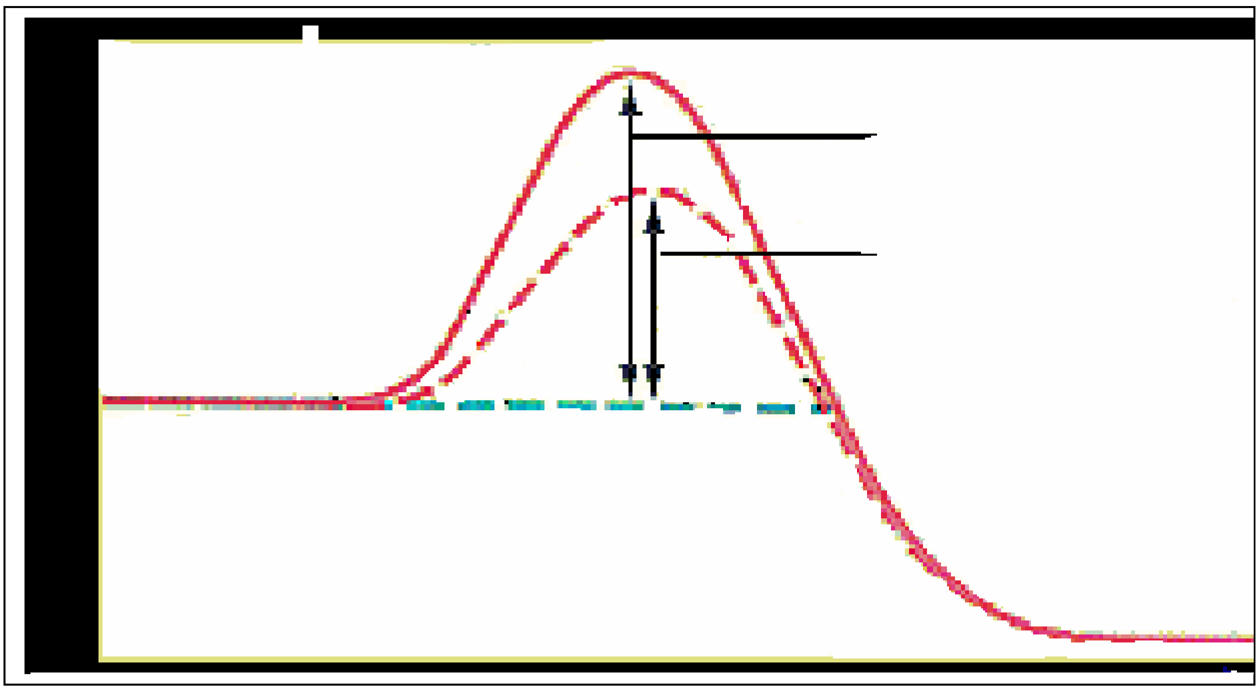
		First Order	**Second Order**
Time	$[C_5H_6]$		
0	0.04		
50	0.03		
100	0.024		
150	0.02		
200	0.0174		

This lesson will comprise of 3 subjects

1. Catalysis
2. Chemical Equilibrium
3. Equilibrium Constants

1. Catalysis

A catalyst is a substance that increases the rate of a chemical reaction without itself being consumed in the overall reaction.



ucts

The catalyst only changes the activation energy required for a reaction to go forward
Activation energy is the minimum amount of energy required to initiate a chemical reaction.

Catalysts are common now, every car has a catalytic converter, which utilizes beads containing platinum, palladium and rhodium, which catalyze the conversion of CO and hydrocarbons to CO_2 and H_2O.

2. Chemical Equilibrium

Chemical equilibrium is achieved when the rates of the forward and reverse reactions are equal and the concentrations of the reactants and products remain constant. In the real world
$A + B \rightarrow C$ does not remove all of A and all of B and form all of C, in a real reaction, there will be some A, some B and some C, the equilibrium constant determines how much of each is left at equilibrium.

To determine the chemical equilibrium constant K_{eq}, use the following example
NOTE ALWAYS products (right hand side) over reactants (left hand side), this is a capital K, which is different than a lower case k which is the rate constant

$$mA + nB \leftrightarrow pC + qD$$

$$K_{eq} \equiv \frac{[C]^p\,[D]^q}{[A]^m\,[B]^n}$$

NOTE look closely at this equation, product over reactants, which means the larger the K_{eq}, the more products you have and the less reactants you are left with.

Here is an example to illustrate:

GIVEN: Gaseous hydrogen iodide partially decomposes to hydrogen and iodine in a 1 Liter vessel:

$$2\ HI\ (g) \leftrightarrow H_2\ (g) + I_2\ (g)$$

At equilibrium HI = 0.00353 moles
H_2 = 0.000479 moles
I_2 = 0.000479 moles

WHAT is the value of K_{eq}?

FIRST- You must convert the equilibrium amounts to moles/L or M (molarity)

So HI = $\frac{0.00353 \text{ moles}}{1 \text{ L}}$ = 0.00353 M = [HI] (the square brackets mean concentration)

This must be done to the rest of the elements giving you:

At equilibrium [HI] = 0.00353 M
$[H_2]$ = 0.000479 M
$[I_2]$ = 0.000479 M

SECOND- Now you can substitute into the equation, be careful of exponents!!

$$K_{eq} \equiv \frac{[C]^p\,[D]^q}{[A]^m\,[B]^n}$$

$$K_{eq} = \frac{[H_2]^1\,[I_2]^1}{[HI]^2}$$

$$K_{eq} = \frac{[0.000479\ M]\,[0.000479\ M]}{[0.00353\ M]^2} = \frac{2.3 \times 10^{-7}\ \cancel{M^2}}{1.25 \times 10^{-5}\ \cancel{M^2}}$$

$$K_{eq} = 0.0184$$

At these conditions, the reaction favors the reactant HI, since K_{eq} is so small, in the vessel, there will be much more HI than I_2 or H_2

this is the constant as the reaction goes forward, from HI to H_2 and I_2, notice the arrow in the reaction points both ways? That is because the reaction can go either way. To determine the equilibrium constant when H_2 and I_2 form HI, simply do $1/K_{eq}$, so the K_{eq} for $H_2 + I_2 \leftrightarrow 2HI$

Is 54.3 (1/0.0184)

NOTE You can see if you are given any 3 of the 4 variables you can solve the equation like if you were given the K_{eq} and concentration of H_2 and I_2, you could solve for equilibrium concentration of HI.

Here are some practice problems for you to try:

GIVEN: Methanol, CH_3OH, is created by the following reaction: $CO\ (g) + 2H_2\ (g) \leftrightarrow CH_3OH\ (g)$
A 2 L vessel at equilibrium contains 0.0406 mol CH_3OH, 0.170 mol CO, 0.302 mol H_2. What is K_{eq}??

Does this reaction favor the product, methanol, or the reactants carbon monoxide and hydrogen??

3. Equilibrium Constants

PART OF SECTION 2, FIND A GOOD PLACE TO BREAK IT

LESSON 5

This lesson will comprise of 3 subjects

1. LeChatelier's Principle
2. Solubility Equilibrium
3. Precipitation and Complex Ions

1. LeChatelier's Principle

In the example in the previous lesson, where there was 0.0406 moles of Methane at equilibrium, is an extremely low amount considering that is what you are trying to get. There must be a way to create more of what you want out of a reaction if you intend the process to be profitable. There are things you can change that will alter the equilibrium constant, and push the reaction in a direction you want it to go.

Think of a reaction as a pot of water, and you want water vapor, are you going to sit around and wait for all of the water to evaporate, or can you speed up the process??
Applying heat to the pot of water will cause it to vaporize much more quickly as water vapor is given off as steam.

LeChatelier's principle deals with changes in temperature, pressure or concentration of one of the compounds. With the change in each of these variables, the concentrations of each chemical at equilibrium will change.

1. **Changing Reactant or Product Concentration**

When a reactant is added **or** product taken away, you increase the net concentration of PRODUCTS

A + B ↔ C+D (add some A, or take away some C, and get more of C+D)

When a reactant is taken away **or** product added, you increase the net concentration of REACTANTS

A + B ↔ C+D (add some C, or take away some S, and get more of A+B)

2. **VOLUME CHANGE**
This only matters when gases are involved (g), not liquids (l), or solids (s). If a liquid or solid is in the equation do NOT count the moles when determining which side has more

Reducing the volume(or increasing pressure) of a gaseous equilibrium mixture causes the system to shift in the direction that reduces the number of moles of gas. (this is where the little g $H_2(g)$ becomes important)

$1N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$
1 + 3 ↔ 2

This reaction will shift to the right, creating more product, because 2 moles on the right is less than 4 moles on the left.

Increasing the volume (or decreasing pressure) of a gaseous equilibrium mixture causes the system to shift in the direction has a larger number of moles of gas.

$1N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$
1 + 3 ↔ 2

This reaction will shift to the left, creating more reactants, because 4 moles on the left is more than 2 moles on the right.

3. **Temperature Increase**

Endothermic ($\Delta H > 0$) Reactants + *heat* ↔ products (holding a beaker will feel cold, because this reaction sucks heat in from surrounding)
(A cup of melting ice) (ice + heat ↔ water)
("En" at the front of endothermic sounds like "in" so you know it brings heat in, and then you can remember what exothermic means because it is just the opposite of endothermic)

Increasing temperature shifts the equilibrium towards the side that absorbs heat (PRODUCTS)
Thus increasing k (equilibrium constant)

A + B ↔ C + D ($\Delta H > 0$) (Temp↑) (get more of C + D)

Decreasing temperature shifts the equilibrium towards the side that expels heat (REACTANTS)
Thus decreasing k (equilibrium constant)

A + B ↔ C+D ($\Delta H > 0$) (Temp↓) (get more of A + B)

Exothermic ($\Delta H < 0$) Reactants ↔ products + *heat* (holding a beaker will feel hot, because this reaction produces heat)
(a propane flame) (propane $+O_2 \leftrightarrow CO_2 + H_2O$ +HEAT)

Increasing temperature shifts the equilibrium towards the side that expels heat (REACTANTS)
Thus increasing k (equilibrium constant)

A + B ↔ C + D (ΔH < 0) (Temp↑) (get more of A + B)

Decreasing temperature shifts the equilibrium towards the side that absorbs heat (PRODUCTS)
Thus decreasing k (equilibrium constant)

A + B ↔ C + D (ΔH < 0) (Temp↓) (get more of C + D)

REVIEW OF TEMPERATURE SHIFTS

1. Endothermic- increase temperature, get more products
2. Endothermic-decrease temperature, get more reactants
3. Exothermic-increasing temperature, get more reactants
4. Exothermic-decreasing temperature, get more products

HERE are some examples of LeChatelier's Principle

Using the equation: $2SO_2$ (g) + O_2 (g) ↔ $2SO_3$ (g) determine which way the equilibrium will shift when the following things are changed, (**ΔH = -**532 kJ):

a. SO_2 (g) is added b. The volume is tripled (increases) c. The mixture is heated

Using the equation: CH_4 (g) + H_2O (g) ↔ $3H_2$ (g) + CO (g) determine which way the equilibrium will shift when the following things are changed, (**ΔH**=+532kJ):

a. H_2 (g) is addedb. CO (g) is removed c. Pressure is doubled d. The mixture is heated

GIVE EXAMPLE WITH A SOLID?????

separated) is introduced to water, part of it dissolves, and part does not. The way to quantify this is with K_{sp}, which is the concentration of the products(ions after separated) divided by the concentration of the reactant(the initial compound).

So for ordinary table salt NaCl, undergoing the following reaction:

$$NaCl \leftrightarrow Na^+ + Cl^-$$

$$K_{sp} = \frac{[Na^+]\,[Cl^-]}{[NaCl]}$$