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CHEM 120 − Physical and Chemical Properties of Matter - Winter 2010

Section/Class #	Time and Room	Instructor	Office	Ext.*	E-mail
001 (#5601)	10:30 am MWF in DC-1350	R.J. Le Roy	ESC 332	84051	leroy@*uwaterloo.ca*

*The phone number for the University of Waterloo is 519-888-4567.

Course Syllabus

Calendar Description: The stoichiometry of compounds and chemical reactions. Properties of gases. Periodicity and chemical bonding. Energy changes in chemical systems. Electronic structure of atoms and molecules; correlation with the chemical reactivity of common elements, inorganic and organic compounds.

Text: R.H. Petrucci, W.S. Harwood, F.G. Herring and J.D. Madura, *General Chemistry (Principles and Modern Applications)*, Prentice Hall, Ninth Edition, 2007. The text comes with a full *Solutions Manual*. The 8th edition of this book is also acceptable.

Several copies of the text and the solutions manual have been placed on reserve in the Davis Centre Library for use in the library. The call numbers are **UWD 1532** (for the text), and **UWD 1534** (for the solutions manual).

Chapter	Topic(s)	class hours
1-4	Review of stoichiometry ……..…….....……..	3
5	Reactions in aqueous solutions …… (including "our" method of balancing of redox reactions – see page 11 of this booklet)	4
6	Gases (including the Van der Waals and virial equations of state) …	4
7	Thermochemistry ……	5
8	Electrons in atoms (including quantum theory of the H atom) …..	6
9	Periodic table and atomic properties …… (including electron configurations of monatomic anions and cations; ignore quantitative aspects concerning penetration and shielding, i.e. equations 9.3, 9.4 and 9.5)	2
10	Chemical bonding and molecular geometry ……	4
11	Quantum theory of chemical bonding ……. (up to and including page 445 of the text; the MO diagram for CO on p. 446 is wrong! σ_{2p} is higher in energy than π_{2p}.)	7
		35

Important dates

Jan. 15: Deadline for adding a course to your schedule
Jan. 22: Deadline for dropping a Course with no penalty.
Feb. 2: Test #1 5:30-7:00 PM
Feb. 15-19: Reading Week
Feb. 26: Deadline for withdrawing from a course
Mar. 9: Test #2 5:30-7:00 PM
Apr. 5: Lectures end
Apr. 9-23: Exam period

Access to Assistance

Office for Persons with Disabilities (OPD): This office collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you have a documented disability, (i.e. physical, learning, or sensory disabilities or chronic medical conditions), you are encouraged to contact this office to determine eligibility for our services. It is recommended that you register with the OPD at the beginning of each academic term, if you anticipate that you require academic accommodations to lessen the impact of your disability. The office is located in Needles Hall, Room 1132.

Counselling Services: The University of Waterloo can be a challenging environment. A meeting with a friendly and experienced counsellor can help you handle and manage your goals. Counselling Services provides a wide range of strategies to help you do your very best during your time at Waterloo. Counselling Services can help you with Study Skills, Career Planning and Personal Goals. For an appointment, call 519-888-4567, extension 32655 or go to Needles Hall, Room 2080. Their web-site is **www.adm.uwaterloo.ca/infocs/**

Avoidance of Academic Offenses

Students are expected to know what constitutes academic integrity, to avoid committing academic offenses, and to take responsibility for their actions. Students who are unsure whether an action constitutes an offense, or who need help in learning how to avoid offenses (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course professor, TA, academic advisor, or the Undergraduate Associate Dean. For information on categories of offenses and types of penalties, refer to Policy #71, Student Academic Discipline, **www.adm.uwaterloo.ca/infosec/Policies/policy71.htm** . Students who believe that they have been wrongly or unjustly penalized have the right to grieve; refer to Policy #70, Student Grievance, **www.adm.uwaterloo.ca/infosec/Policies/policy70.htm** .

Learning Outcomes

CHEM 120 (Physical and Chemical Properties of Matter) and CHEM 123 (Chemical Reactions, Kinetics and Equilibria) comprise a full year course in "general chemistry". These courses lay the foundation for more advanced chemistry courses including organic chemistry (e.g. CHEM 264 or 266), inorganic chemistry (e.g. CHEM 212), analytical chemistry (e.g. CHEM 220), physical chemistry (e.g. CHEM 254) and biochemistry (e.g. CHEM 233 or 237).

By the end of this course, you should be able to explain trends in certain physical and chemical properties of matter in terms of the electronic structures of atoms and molecules. More specifically, this course is designed so that by the end, you should be able to:

- identify and describe the different types of reactions that occur in aqueous solutions
- apply stoichiometric and thermodynamic principles to quantify the amounts of reactants, products and energy consumed by or produced by a chemical reaction
- describe the behaviour of molecules in gases and predict the properties of gases
- describe the electronic structure of atoms and justify the organization of the periodic table
- predict trends in the properties of the elements
- predict and visualize the three-dimensional structures of molecules, and assess which structures are most important when more than one structure is plausible
- describe bonding in molecules in terms of atomic orbitals and molecular orbitals, and understand molecular shape and stability in terms of electron count

Learning Methods

Lectures: You (with your class) will meet with your instructor three times per week, as shown in the table at the top of the first page. During lectures, your instructor will focus on selected topics and he/she will assume that you will have prepared for each lecture by reading ahead in his/her course notes or the text. During lectures your instructor will focus on selected topics. He/she will not devote time to all topics discussed in the text. You may have to learn some of the course material on your own.

On-line Assignments: The assignments in CHEM 120 provide you with an opportunity to apply the concepts introduced during lectures. Most assignments are provided on-line so that you can obtain frequent and immediate feedback on your understanding of the concepts. Each on-line assignment can be repeated up to four times, so that you can correct your mistakes or get help whenever you need it. More detailed information about the on-line assignments is provided on page 5 of this course information booklet.

Problem Sets: A modest number of problems will be assigned for which written solutions are to be turned in as part of the "Assignments" component of your mark.

On-line "mini-lectures": You will find mini-lectures" on all topics in CHEM 120 in the "Mini-Lectures" folder on our course web-site on UW-ACE. (More information about UW-ACE is provided on page 4 of this course information booklet.) Your lectures and textbook are the primary sources of information for this course, but you can use these mini-lectures whenever you are seeking more information or a different perspective.

Homework Problems: For each week of term, we have assigned problems for you to try. (See pages 8-10 of this course information booklet.) You are not required to hand in solutions to these problems; the responsibility to do them is yours.

Make sure you can do all of these assigned homework problems!

Office Hours: Not all learning happens in the classroom. You may find it necessary to meet with your course instructor during his office hours to get some one-on-one help. Your instructor will expect you to come prepared with a specific question or questions. (e.g., In reviewing my notes, I understand up to this point, but I get confused here.) It is not a beneficial use of your time, or your instructor's time, to show up and say "I just don't get (insert specific topic)."

Learning Assessment

Assignments (10%): Most assignments will be done on-line and accessed via MapleTA. See pages 4-5 of this course information booklet for more information. If you choose not to do the on-line homework assignments, then the 10% weight for the assignments is transferred to the tests and exams, with 2.5% going towards each of Test #1 and Test #2 and 5% going towards the final exam.

Term Tests (30%): There will be two 80-minute term tests, each worth 15% of the course grade. The tests will be held on **Tuesday Feb. 2** and on **Tuesday Mar. 9** (rooms TBA). The seating plans for the term tests will be announced in class (and on UW-ACE) in the week prior to the tests.

Final Examination (60%): There will be a 2.5-hour exam held during the exam period (Apr. 9-23). The examination is scheduled by the Registrar. Normally, the examination schedule is posted in early March. Until you know the date of your last examination, **don't make plans to leave campus before April 23.**

Important!! The learning assessment described above applies only if the weighted average of your tests and exam is at least 45%. If the weighted average of your tests and exam is less than 45%, then that weighted average is also your course

Why do we place extra emphasis on the weighted average of your tests and exam? Our experience, compiled over many years with tens of thousands of students passing through CHEM 120, indicates that your results on the tests and exam are the best indicator we have of gauging your readiness for and chance of success in other chemistry courses. Low marks on the test and the exam are a very strong indicator that you are not yet ready to move on to other chemistry courses. Keep in mind, however, that the assignments are an important part of getting you ready for the tests and exams. It is in your best interests to do the assignments, and learn from your mistakes.

Important Policies for CHEM 120

(1) Calculators: You may bring a non-programmable calculator to the tests and the exam. If your favourite calculator is programmable (or can store textual information), then you must take your calculator to a proctor before the test and show him/her that you have cleared the memory. The following calculators are highly recommended: **Sharp EL-531W, TI 30X II (S or B), and Casio fx-260**. These calculators can be purchased at various stores as well as on campus. The Sharp and TI models have been adopted by the Math Faculty for use in first-year math courses, so if you are also taking MATH courses, you should consider one of those models.

(2) Absence on the day of a test or exam: If you miss any examination, either a midterm or final, then you shall be given a grade of zero on that examination unless you missed the examination for valid reasons (e.g. illness). If you miss an examination because of illness, you must provide a completed Verification of Illness Form, which can be obtained from the Health Services web-site (***http://www.healthservices.uwaterloo.ca/sitemap.html***). The completed form must first be registered with the Science Undergraduate Office (ESC 253). The Undergraduate Office will keep the original form for their records and forward the relevant information to your instructor. The completed form must specify the precise period of absence. If you become ill while away from the University and miss a test or an exam as a result of that illness, then you may supply a Doctor's certificate covering the precise period of absence, provided the certificate includes a classification of the illness as slight, moderate, or severe. In all cases, the letter or form must include contact information of the person who signed the letter or form, and it must be registered with the Science Undergraduate Office.

A Verification of Illness Form (VIF) or a doctor's note does not necessarily excuse a student from missing a test or exam! The instructors and course coordinator will consider the information provided on the VIF or doctor's note when deciding whether a student should be excused. Being excused from a test or exam is NOT automatic upon the presentation of suitable medical verification. Students should carefully consider the wisdom of missing a test or exam. The following rules apply when it is decided that a student has a legitimate excuse for missing a term test or exam..

- If it is decided that a student has a legitimate excuse for missing a term test, then the weight of the term test will be transferred to the final examination. (There are no make-up term tests!)
- If it is decided that a student has a legitimate excuse for missing the final exam, then he/she will normally write a make-up exam next December together with students taking CHEM 120 in the Fall 2010 term.

Important Web Sites (Bookmark these sites!)

UW Home Page (*http://www.uwaterloo.ca/*)
This is the main UW Home Page. Use the links and/or search engine to find other important UW web-sites.

Registrar's Office (*http://registrar.uwaterloo.ca/*)
The Registrar's Office provides administrative services to all students in a number of areas. The Registrar's Office is where you would go to request a transcript, drop off course override forms and much more. Before going to the Registrar's Office, consult the web-site to obtain important information and/or forms (e.g. plan modification forms, course override forms, etc.)

Quest (*http://www.quest.uwaterloo.ca/*)
Quest is the University of Waterloo's student information system. As a student at UW, you can use Quest to perform a number of important tasks (e.g. update your contact information; view your tuition fees and account summary; pay your fees; view your term grades or unofficial transcript; enrol in, drop, or swap classes; view your class schedule; view the UW course catalogue and Schedule of Classes, etc.)

UW-ACE (*http://uwace.uwaterloo.ca/*)
ACE stands for "Angel Course Environment". Angel is a web-based course management system that enables instructors to manage course materials and communicate easily and efficiently with their students. When you go to the UW-ACE web-site, you will be prompted for a username and password. Use the same username and password that you use for logging onto Quest. After you log onto UW-ACE, you will see CHEM 120 listed as one of your courses. (Note: Not all of your instructors will be using UW-ACE, so you may not see all of your courses listed!!) I will use UW-ACE for CHEM 120 to post useful information, announcements, *my outline lecture notes*, and important links. You will also find extra problems, sample tests and sample exams. **Make sure you log onto UW-ACE regularly.**

Library Resources

We have placed the following items "on reserve" in the Davis Centre Library. **These resources are for library use only.** You may borrow these items by giving the attendant at the Reserve Desk the appropriate catalogue number. (e.g. Ask for UWD 1532 if you want to borrow the textbook.)

Libray Reserve Item	**Catalogue Number**
Course text (by Petrucci, Harwood & Herring)	UWD 1532
Solutions manual (for the text above)	UWD 1534

Another useful chemistry resource that can be found in the Reference section of the library is the **CRC Handbook of Chemistry and Physics** (Ref. QD65.H3). This handbook lists, among other things, chemical and physical properties of essentially all organic and inorganic substances that are known. The CRC Handbook of Chemistry and Physics can be accessed on-line, free of charge, from any ".uwaterloo.ca" address. The URL is ***http://www.hbcpnetbase.com/***

On-line Assignments

In this course, we use an on-line homework assessment system, called MapleTA, to deliver on-line assignments. The on-line assignments give you a chance to build your skills gradually and, because they are delivered on-line, you obtain frequent and immediate feedback about your progress.

Your user account on the the MapleTA system will NOT be available until the second week of term. Announcements will be made in class and on UW-ACE to let you know when you will be able to access your user account and the on-line assignments. When it is announced that the user accounts and on-line assignments are available, follow these steps to access them.

(1) Go to **http://mapleta.uwaterloo.ca** (You can access this site using the link provided in UW-ACE. When you get to the MapleTA web-site, bookmark it so that you can access the on-line assignments even if UW-ACE is unavailable.)

(2) Log on to the MapleTA system using your UW-ACE username as your login name and your UW student number as your password.

(3) Change your password. To change your password, click on the link entitled "My Profile" (in the upper right hand corner of the screen) and then on the link entitled "Password Update". We suggest that you use the same password that you use to log in to UW-ACE, Quest, etc. to minimize the possibility of forgetting your password. The next time you log in, you will have to use your new password.

(4) Find our class (CHEM 120, Fall 2009). The course coordinator (C. Bissonnette) is listed as the instructor of the course. All students in CHEM 120 access the same class (i.e., your instructor does not have his or her own class in MapleTA!!) There are many courses using MapleTA this term, so make sure you have found our class.

If you forget your password, or require assistance with your account, then contact one of the people below. These contacts cannot help you with chemistry-related questions! They can only resolve technical issues related to your MapleTA account.

Paul Kates, Mathematics & Engineering Faculties CTE Liaison (pkates@uwaterloo.ca, ext. 37047)

Carrie Howells, Instructional Support Coordinator, Mathematics Faculty/MFCF (cahowells@math.uwaterloo.ca, ext. 36272)

Important!! If you wish to connect to the MapleTA web-site using UW's wireless network, then you must first run MinUWet to ensure that the internet security is up-to-date. (For more information, go to http://www.minuwet.uwaterloo.ca)

Guidelines concerning the on-line homework assignments

(1) **Each assignment is available for a limited period of time**, so it is imperative that you monitor the assignment deadlines carefully. Do NOT wait until the last minute to do your assignment! (If you wait until the last minute, you will not have time to resolve technical difficulties or get help.)

(2) **Print off a paper copy of every assignment and work on the problems at home.** When you have finished those problems, return to MapeTA, enter your answers and then submit your assignment for grading. Note carefully: Your instructor or Tutor cannot help you with your assignment if you do not have a paper copy of your assignment!!

(3) **You can attempt each assignment up to four times.** We save only the highest mark you achieved. Each time you attempt an assignment, you get the same set of questions so that you can correct your mistakes or get help whenever you need it.

(4) **Do not waste attempts by guessing or changing your answers one at a time.** If you cannot figure out why your answers are wrong, or when you are struggling with the assignment problems, take your paper copy of the assignment to a teaching assistant or your instructor to get some help before you use up all of your attempts.

(5) **Do the assignments one at-a-time, in the proper order!** The assignments are designed to be done in order. So, you should complete Assignment #1 before accessing or attempting Assignment #2. Also, if you try to access Assignment #2, for example, before you finish or submit answers for Assignment #1, the system will automatically grade Assignment #1 (even if you have not yet inputted any answers!) and you will use up one of your attempts at Assignment #1.

(6) **Every time you achieve a grade of 80% or higher on an assignment, the mark will be treated as 100%** when calculating your assignment average at the end of term. Otherwise, we use your actual mark on the assignment when calculating your assignment average.

What We Expect You to Know Already

When you browse the list of topics given on the front page, or the chapter titles in your text, you might be tempted to think that you know most of the material already. Don't be fooled! We guarantee you that we will explore in more detail some topics you've seen before (especially for thermochemistry and the electronic structures of atoms and molecules). Don't take this to mean that we are dismissing what you learned in high school. We will use your previous exposure to chemistry as a "catalyst" to bring about a much deeper understanding of fundamental concepts in chemistry.

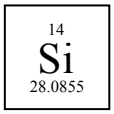
Build a strong foundation! Together, the two courses CHEM 120 and 123 comprise a full year course in "general" chemistry. These courses lay the foundation for more advanced chemistry courses including organic chemistry (e.g., CHEM 264 or 266), inorganic chemistry (e.g., CHEM 212), analytical chemistry (e.g., CHEM 220), physical chemistry (e.g., CHEM 209 and 254), and biochemistry (e.g., CHEM

You have already taken the equivalent of two full courses of high school chemistry, but it may have been more than one year since you took your last chemistry course. It is not unrealistic to assume that you have forgotten some of what you learned. During the first week of term, your instructor will review some basic concepts but he will not undertake a comprehensive review. **You must review carefully Chapters 1-3 of the text on your own during the first week!**

We shall presume that:

- you know basic concepts from physics (e.g. kinetic versus potential energy; force, work, velocity, acceleration). See Appendix B for a review of some basic physical concepts.
- you know all of the SI base units and SI prefixes (from **tera** through to **femto**). See Tables 1.1 and 1.2 of the text.
- you can determine the number of significant figures in a given quantity and can round off the result of a calculation to the correct number of significant figures. See section 1-7 of the text.
- you understand terms used to describe the physical properties of matter (e.g. temperature; density, homogeneous versus heterogeneous mixtures). See Sections 1-2 through 1-5.
- you know basic concepts and terminology associated with atoms and atomic structure (e.g. electron, proton, neutron, atomic number, mass number, atomic mass unit, isotope, natural abundance, mole, molar mass). See sections 2-1 through 2-8 of the text, as well as sections 3-1 through 3-3.

- you have a "working" knowledge of the periodic table (e.g., atomic symbols and names, period versus group) and the meaning of the numbers given for each element. (e.g., what information is conveyed by "14" and "28.0855" in the box for Si?) . See sections 2-4 through 2-6 of the text.



- you understand the meaning of terms such as empirical formula, molecular formula; structural formula; anion; cation; oxidation state; limiting reagent; excess reagent; actual, theoretical and percent yields; molarity.
- you are familiar with the names and formulas of simple inorganic compounds. Familiarize yourself with Tables 3.1, 3.2, and 3.3 in the text.
- you can balance simple chemical equations by inspection (e.g. $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$). Some chemical equations are impossible to balance by inspection (e.g., "redox" reactions that occur in aqueous solution), and we must use special methods to balance them. See sections 4-1 through 4-3 for a discussion of how to balance a chemical equation by inspection.
- you are proficient in the use of exponential (i.e., scientific) notation; logarithms (e.g., log's and ln's); exponentials (e^x); the quadratic formula. See Appendix A of the text for an overview of mathematical operations.
- you can solve one linear equation in one unknown (e.g., If $\frac{2\,m}{95.21} + \frac{0.5200 - m}{58.44} = 9.0 \times 10^{-3}$, then what is m?). In some instances it may be helpful if you can solve two linear equations in two unknowns (e.g. If $95.21x + 58.44y = 19.54$ and $2x + y = 0.390$, then what are x and y?) See Appendix A of the text.
- you can use a table of (x,y)-data pairs to construct a plot (see Appendix A). For straight line plots, it is expected that you can calculate the slope.

How to Study Chemistry Effectively

If you are typical of most first-year students, your biggest challenge is to develop mature study-habits: keeping up to date with the material, reading ahead, and working on problems within and at the end of chapters. Ideally, you will work (and learn) from your text book and stay ahead of your instructor throughout the term. This will help you get the most of lectures. By working ahead, you can identify topics you find difficult **before** they come up in lectures. (If your instructor's explanation does not help you understand these difficult concepts, ask for clarification during lectures.)

Interested in a "study-skills" package or an "exam prep" workshop? Call Counselling Services (519-888-4567, ext. 32655) or visit *http://www.adm.uwaterloo.ca/infocs/*

It is our experience that many first-year students are reluctant to change (and improve!) their study methods. From now on, you are expected to learn a lot of material in a short period of time. In CHEM 120, we cover 500 pages of the text in less than 35 hours of class time. You should not presume that the study methods you've developed up to this point are as good as they can be.

Most of your time in this course should be spent solving problems, but don't view problem-solving as a matter of identifying all possible types of problems and how to solve them. Your instructors will always find new ways of asking questions to test whether you understand the underlying concepts! **Focus on learning the basic principles and definitions so that you can apply them in each new situation.**

You can work through this course at a reasonable pace if you follow the schedule given on pages 8-9 of this booklet. The schedule we've suggested encourages you to work ahead of your instructor and allows you to build your problem-solving skills gradually. For each week of term, there are problems from your text and often some extra problems prepared by the instructors. You are not required to hand in solutions to these problems; the responsibility to do them is yours. **You should be able to do all of the problems at the end of the chapters, not just the ones we've listed as representative examples.**

Getting the most from your textbook

Don't read your text passively as if it were a novel! It is not effective to read an entire chapter once and then attempt to do the problems at the end of the chapter. Be an active reader and think about what you are reading. Before going on to the next section, stop and ask yourself questions (e.g., "What is the difference between a strong electrolyte and a weak electrolyte?"). Write your questions in the margins of the text or on a separate piece of paper. If you can't answer the questions you've compiled, go back and re-read that section of the text. The questions you write down can later be used to help you review for a test or exam. **Answering questions on exams will produce less anxiety if you have been asking and answering questions all along!**

Think about it! A question in the margin prompts you to stop, think and answer. Highlighting your text with a marker, or copying sentences from the text, emphasizes memorization over understanding.

Make sure you try the worked examples from the text (and in your lecture notes) for yourself. Don't just read through the solution. You will not know for sure that you can do the problem until you try. Don't wait until a test or an exam to try! Cover up the solution given in the text (or your notes) and work through the problem yourself. Compare your method and answer to those given. **If you get stuck, look at the solution but then change the numbers and re-work the problem yourself.** Don't underestimate the importance of the examples done in class. (Your instructor selects examples to illustrate certain concepts, and sets questions on the exams to test whether you understand those concepts.)

Some general advice concerning the homework assignments

As the result of marking thousands of final exams in recent years, we believe that almost all students need help in improving their problem-solving skills and with presenting their thoughts in a clear, concise, and understandable form. Problem-solving is not just about doing a lot of problems or substituting numbers into a formula and getting an answer. You must always think about what you are doing and why.

- Ask yourself questions before going on to the next problem to force yourself to think about what you are doing and to explain things in your own words.

e.g., Did I make any assumptions or approximations in solving this problem? Are the assumptions valid in this case? Is my answer reasonable? Is there another way to do this problem? What variations of this problem can I think of ?

- Use a neat and orderly approach when writing out your solutions. This will help immeasurably when you are reviewing for a test or exam, and especially when someone is grading your work. A neat approach will keep a marker's "kindness quotient" high!
- Explain your steps. Don't assume it's obvious!
- Always include units. If the units work out properly, it is possible your answer is correct. If the units do not work out, you know your answer is wrong.

Stoichiometry: The "basics"

Stoichiometry is concerned with "quantifying" the composition of compounds and mixtures, as well as the amounts of reactants and products involved in a reaction. We know that you have had exposure to stoichiometry in your previous chemistry courses (perhaps more than a year ago!), and that is why we are placing the onus on you to re-familiarize yourself with this material. This brief section is meant only to provide some guidance.

In everyday applications, we quantify the amount of substance by specifying, for example, its mass or its volume. However, the chemist expresses the amount of substance in units of **moles**. The abbreviation for this unit is **mol**.

$$1 \text{ mol} \equiv 6.022 \times 10^{23} \text{ particles}$$

Note: Your instructor will review the reasons why the mole is defined this way.

We normally reserve the symbol "*n*" to represent the number of moles of a substance and use a subscript to identify the substance we are talking about. For example, we could use the symbol n_{Mg} to denote the number of moles of magnesium.

When doing "stoichiometry problems", it is often helpful to keep the following approach in mind:

1. **Convert macroscopic quantities to moles** (e.g., convert grams of X into moles of X).
2. **Convert moles of one substance into moles of some other substance** (e.g., convert moles of X into moles of Y using a balanced chemical equation for the reaction involving X and Y).
3. **Convert from moles to the macroscopic quantity required** (e.g., convert moles of Y into grams of Y).

In short, this method involves the following conversions: **"to moles"**, **"between moles"** and **"from moles"**. The "chemistry" of the problem appears in the second step. The steps can be applied separately or can be combined into a single step. The following example illustrates the point.

Example: Nitrogen gas, N_2, can be prepared by passing gaseous ammonia over solid copper (II) oxide, CuO, at high temperatures. The balanced equation for the reaction is

$$2NH_3(g) + 3CuO(s) \rightarrow N_2(g) + 3Cu(s) + 3H_2O(g)$$

In a certain experiment, 18 g NH_3 is combined with an excess of CuO. Calculate the maximum mass of N_2(g) that can be obtained from this reaction mixture.

A quick word about significant figures: Always retain extra digits in your intermediate calculations. In this example, our final answer must have two significant figures, so we must retain at least three digits in the

Solution:

Convert to moles: $n_{NH_3} = 18\ g\ NH_3 \times \frac{1\ mol\ NH_3}{17.03\ g\ NH_3} = 1.06\ mol\ NH_3$

Convert between moles: $n_{N_2} = 1.06\ mol\ NH_3 \times \frac{1\ mol\ N_2}{2\ mol\ NH_3} = 0.528\ mol\ N_2$

Convert from moles: $m_{N_2} = 0.528\ mol \times \frac{28.02\ g\ N_2}{1\ mol\ N_2} = 15\ g\ N_2$

Note: We use molar masses (e.g. 17.03 g mol^{-1} and 28.02 g mol^{-1}) as well as the coefficients from the balanced chemical equation (e.g., 1 mol N_2 requires 2 mol NH_3) as **conversion factors**. Of course, you may combine the steps into a single step, as shown below.

$$m_{N_2} = 18\ g\ NH_3 \times \underbrace{\frac{1\ mol\ NH_3}{17.03\ g\ NH_3}}_{\text{converts to moles}} \times \underbrace{\frac{1\ mol\ N_2}{2\ mol\ NH_3}}_{\text{converts between moles}} \times \underbrace{\frac{28.02\ g\ N_2}{1\ mol\ N_2}}_{\text{converts from moles}} = 15\ g$$

Notice, however, that the long conversion factor shown above incorporates three separate conversion factors. With practice, you will be able to do many of your calculations in a single step.

Weekly Problem Sets

Ideally, you will work (and learn) from your text book and stay ahead of your instructor throughout the term. This will help you get the most out of lectures. By working ahead, you can identify topics you find difficult **before** they come up in lectures. The schedule below encourages you to work ahead of your instructor, and allows you to build your problem-solving skills gradually.

	Representative Problems (from Petrucci, Harwood, Herring & Madura, 9th edition)	Extra problems (see pages 9-10)
Week 1, Jan. 4-8	Chapter 2: 8, 25, 39, 40, 43, 53, 56, 59, 71, 78 Chapter 3: 6, 8, 11, 14, 16, 18, 23, 25, 26, 33, 37, 42, 44-46, 51, 52, 59, 60, 61, 62, 69, 70, 80, 85, 86, 89, 91, 93, 97, 100 **Note: You will not be tested explicitly on inorganic or organic nomenclature. On tests and exams, we might identify a substance by name only. Therefore, you must develop a familiarity with the names of common substances, and simple inorganic and organic compounds. See Tables 3.1, 3.2, 3.3 and 3.5 of the text.	
Week 2, Jan. 11-15	Chapter 4: 1, 2, 5, 6, 7, 9, 15, 18, 21, 30, 32, 38, 41, 42, 44-46, 49, 54, 61, 62, 64-67, 71, 73, 76, 79, 80, 82, 84, 85, 90, 93, 97	B1, B2
Week 3, Jan. 18-22 **Course Drop Deadline #1 is January 22..**	Chapter 5: 1, 7, 18, 19-22, 27, 28, 30, 33, 37-42, 50, 52, 57, 63, 65, 67, 77, 78, 81, 83, 87, 89, 90 Chapter 6: 9, 10, 23, 25, 27, 30, 32, 36, 40, 43-47, 49, 50, 52, 53, 55, 56, 63, 64, 66, 82, 86, 88, 91, 95	B3, B4, B5, B6, B7
Week 4, Jan. 25-29 **Test #1 is on Oct. 9th.**	Chapter 6: 67, 71, 74, 75, 78, 104 ** Problem 104 makes use of the virial equation of state. Chapter 7: 5, 7, 9, 12, 13, 15, 18, 22,26, 30, 31, 34, 39, 41, 43, 45, 46, 48	B7- B9
Week 5, Feb. 1-5 **Test #1 is on Tuesday Feb. 2**	Chapter 7: 51-53, 56, 57, 61, 63, 65-67, 70, 72, 77, 84, 87, 88, 93, 96	
Week 6, Feb. 8-12 **(Reading week is Feb. 15-19)**	Chapter 8: 13-15, 20, 25, 29, 33, 40, 41, 45	
Week 7, Feb. 22-26 **Course Drop Deadline #2 is Feb. 26th**	Chapter 8: 49, 54, 56, 59-61, 71, 73, 75-78, 80, 85, 86, 90, 91, 101, 107, 117(a)	B10-B13

Week 8, Mar. 1-5	Chapter 9: 9, 11, 12, 14, 21, 28, 33, 40, 59	B14
Week 9, Mar. 8-12 **Test #2 is on Tuesday Mar. 9.**	Chapter 10: 3, 4, 16-19, 21, 22, 33, 34, 37, 45-47, 53, 54, 60, 65, 66, 69, 70, 76, 81, 82, 84, 85, 90, 93, 98	B15
Week 10, Mar. 15-19	Chapter 11: 7, 9, 12, 14-17, 19, 24, 61, 62, 68, 72, 74	B16, B17
Week 11, Mar. 22-26	Chapter 11: 26, 28, 30, 32, 35, 38	B18-B20
Week 12, Mar. 29-Apr.5 **No classes Friday Apr. 2** **Lectures end Mon. Apr. 5st** **Exams start Apr. 9th**	Catch-up and/or review.	

Extra Problems for CHEM 120 **(Solutions will be available on the course home page.)**

B1. After dissolving 2.21 g of a mixture of Na_2SO_4 and NaCl in water, you add an excess of $BaCl_2$ solution. You then filter off the $BaSO_4$ which forms, dry it, and find that it weighs 2.57 g. What is the percent, by mass, of Na_2SO_4 in the original mixture? (Answer: 70.8% Na_2SO_4)

B2. A 2.00 g mixture of $CaCl_2$ and $Ca(NO_3)_2$ is dissolved in water. Addition of a solution of $AgNO_3$ causes all the chloride ion to precipitate as AgCl. When the AgCl is collected and dried, it is found to weigh 3.15 g. What is the percent, by mass, of $CaCl_2$ in the original mixture? (Answer: 61.0% $CaCl_2$)

B3. A 2.00 g mixture of $CaCl_2$ and RbCl is dissolved in water. Addition of a solution of $AgNO_3$ causes all the chloride ion to precipitate as AgCl. When the AgCl is collected and dried, it is found to weigh 3.45 g. What is the percent, by mass, of RbCl in the original mixture? (Answer: 61.4% RbCl)

B4. After dissolving 1.430 g of a mixture of Na_2SO_4 and $Al_2(SO_4)_3$ in water, you add an excess of $BaCl_2$ solution. You then filter off the $BaSO_4$ precipitate which forms, dry it, and find that it weighs 2.540 g. What is the percent, by mass, of $Al_2(SO_4)_3$ in the original mixture? (Answer: 33.0% $Al_2(SO_4)_3$)

B5. Use the half-reaction method discussed in class to complete and balance the following reaction which occurs in acidic solution: $Cr_2O_7^{2-}(aq) + H_2O_2(aq) \rightarrow Cr^{3+}(aq) + O_2(g)$. **The method is described on the next page.**

B6. Use the half-reaction method discussed in class to complete and balance the following reaction which occurs in basic solution: $MnO_4^-(aq) + C_2O_4^{2-}(aq) \rightarrow MnO_2(s) + CO_3^{2-}(aq)$. **The method is described on the next page.**

B7. A gas cylinder contains 3.50 mol N_2, 7.45×10^{23} molecules of O_2, and 39.0 g of CO.What is the gas pressure in the cylinder at 25°C if the volume is 12.5 L? (Answer: 1.22×10^3 kPa)

B8. When O_2 gas is contained in an effusion apparatus, 0.0384 mmol escape in 493 seconds. When gas X is in the apparatus, 0.0252 mmol escape in 693 seconds. What is the molar mass of X? (Answer: 147 g mol^{-1})

B9. The density of liquid benzene, $C_6H_6(l)$, is approximately 0.88 g mL^{-1} at all temperatures. The standard enthalpy of vaporization of $C_6H_6(l)$ is 30.8 kJ mol^{-1} at 353 K, its normal boiling point. Calculate the pressure-volume work (w) and the internal energy change (ΔU) when one mole of liquid benzene is vaporized at 353 K under a constant pressure of 101 kPa. (Answer: $w = -2.93$ kJ, $\Delta U = 27.9$ kJ)

B10. The energy conservation principle that applies to the photoelectric experiment is $E_{photon} = (KE)_{electron} + W$, where W is the "work function" for the metal. (The work function is the minimum energy required to eject an electron from the metal surface.) The work function for calcium metal is 4.60×10^{-19} J. If calcium is irradiated with 400-nm photons, what is the de Broglie wavelength of the resulting photoelectron beam? (Answer: 2.6 nm)

B11. Examine the plots of ψ^2 versus r shown in the upper portion of Fig. 9-23 of Petrucci, Harwood and Herring (8th edition) Focus on the right hand portion of each plot only (i.e. the region with $r > 0$).
a) What is the relationship between the number of radial "nodes" and the values of n and l?
b) Sketch a plot of ψ^2 versus r for a 4s orbital.

B12. Examine the plots of $4\pi r^2 R^2$ versus r that are given in **Fig. 8-35** of the text.
a) What is the relationship between the number of "humps" and the values of n and l?
b) Sketch a plot of $4\pi r^2 R^2$ versus r for a (i) 4*s* orbital (ii) 4*p* orbital (iii) 4*d* orbital

B13. What does a plot of R^2 versus r tell us? What does a plot of $4\pi r^2 R^2$ versus r tell us?

B14. In class you learned that for a **transition metal <u>atom</u>** in the fourth row, the 4*s* orbital fills before the 3*d* orbitals. This "rule" does not hold for a transition metal ion. For a **transition metal <u>ion</u>**, the 3*d* orbitals are lower in energy than the 4*s* orbital and consequently, the 3*d* orbitals fill first. (Your text book says that to obtain the correct electron configuration for a transition metal ion, you write the electron configuration for the neutral atom and then remove electrons with the highest value of n first. The text's approach will not always give you the correct configuration.)
a) What is the ground-state electron configuration of Zn^{2+}?
b) For <u>one</u> of the valence electrons, give acceptable values of n, l, m_l and m_s.
Repeat parts a) and b) for the Cu^{3+} and Fe^{+} cations.

B15. Use Hess' Law, together with the data given below, to calculate the standard enthalpy of formation of zinc oxide.
<u>Hint</u>: Write down chemical equations for ionization, sublimation, etc. and then decide how to combine those chemical equations to obtain the formation reaction. (Answer: –301 kJ/mol)

$ZnO(s) \rightarrow Zn^{2+}(g) + O^{2-}(g)$, $\Delta H = 4059$ kJ/mol
Ionization energies for Zn(g): first IE = 906.4 kJ/mol, second IE = 1733 kJ/mol, third IE = 3832 kJ/mol
Bond dissociation energy for $O_2(g)$, 498.3 kJ/mol
Enthalpy of sublimation of Zn(s), 130.73 kJ/mol
Electron affinities for O(g), first EA = –141 kJ/mol, second EA = +880 kJ/mol
Ionization energies for O(g): first IE = 1314 kJ/mol, second IE = 3388 kJ/mol, third IE = 5300 kJ/mol

B16. Draw the Lewis structure for the ethanal molecule, $H_3C\underline{C}HO$. (Note: Both the H and O atoms are bonded to <u>C</u>.)
a) Use the valence bond approach to explain the bonding in this molecule. (Consult Figs. 12-14 through 12-17 for similar examples and to see what is expected of you.)
b) Which one of the two bonds, C-C or C-O is likely to be the weaker in this molecule. Explain why you think so.

B17. Consider the allene molecule, H_2CCCH_2. Draw the Lewis structure for H_2CCCH_2 and answer the questions below.
a) Classify each bond as σ or π and identify the orbitals involved. (See Figs. 12-14 through 12-17 of the text to see what is expected of you.)
b) What is the H-C-C bond angle? What is the C-C-C bond angle?
c) Explain why the four hydrogen atoms <u>cannot</u> all lie in the same plane.

B18. Draw and label the molecular orbital energy level diagram for the superoxide ion, O_2^-, and insert the electrons in the appropriate orbitals for the ground state of this molecule. What is the bond order ?

B19. Write ground-state electron configurations for C_2 and O_2. Explain why adding an electron to C_2 has a stabilizing effect while adding an electron to O_2 is destabilizing.

B20. Use the MO diagram for N_2 to explain why the first ionization energy of N_2 (IE_1 = 1501 kJ mol^{-1}) is greater than the first ionization energy of atomic nitrogen (IE_1 = 1402 kJ mol^{-1}). Also, calculate the wavelengths of light required to ionize N_2 and N. (Assume that ionization of an atom or molecule is caused by the absorption of a single photon of the appropriate energy.) To what regions of the electromagnetic spectrum do these wavelengths correspond?

A method for completing & balancing equations for oxidation-reduction reactions that occur in acidic or basic aqueous solution

Water molecules, protons (H^+) and hydroxide ions (OH^-) are present in all aqueous solutions and must be accounted for when writing a complete, balanced equation for an oxidation-reduction reaction in aqueous solution.

Many text books give one method for completing and balancing redox reactions in acidic solutions and another for basic solutions. The following method *may be used in all cases*; **it is strongly recommended.** It is sometimes helpful to eliminate "spectator" ions from the equation before you attempt to balance it. The spectator ions can be added back into the equation after it has been balanced.

Steps:

1. Assign oxidation states to each element in the reaction, and identify the species being oxidized and reduced.
2. Write separate half-reactions for the oxidation and reduction processes.
3. Balance the separate half-reactions:
   a) first with respect to the element being oxidized or reduced, and
   b) then by adding electrons to one side or the other to account for the number of electrons produced (oxidation) or consumed (reduction).
4. Combine the half-reactions algebraically so that the total number of electrons cancels out.
5. Balance the net charge by either adding OH^- to one side of the equation (for basic solutions) or H^+ to the other (for acidic solutions).
6. Balance the O and H atoms by adding H_2O.
7. Check that the final equation is balanced with respect to each type of atom and with respect to charge.

Here is the Data Sheet from a recent final exam. This sample data sheet will give you an idea of what information will be provided for you. Other data (e.g. standard enthalpies of formation, bond energies) may be given on the data sheet or as part of the question that requires them. You are not required to memorize numerical data.

DATASHEET

1 1A												13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008	2 2A																2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3 3B	4 4B	5 5B	6 6B	7 7B	8 ←	9 8B	10 →	11 1B	12 2B	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	(57-71) **La-Lu**	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226	(89-103) **Ac-Lr**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Uun**	111 **Uuu**	112 **Uub**	113 **Uut**					

Constants:

$N_A = 6.022\times10^{23}$ mol^{-1} $R_H = 2.179\times10^{-18}$ J (Rydberg constant)

R = 0.082058 atm L K^{-1} mol^{-1} $c = 2.998\times10^{8}$ m s^{-1} $e = 1.602 \times 10^{-19}$ C

= 8.3145 kPa L K^{-1} mol^{-1} $h = 6.626\times10^{-34}$ J s $\pi = 3.141592654$

= 8.3145 J K^{-1} mol^{-1} $m_e = 9.109\times10^{-31}$ kg

Conversion factors:

1 atm = 101.325 kPa 1 kPa L = 1 J = 1 Pa m^3 1 cal = 4.184 J 1 nm = 10^{-9} m

1 atm = 760 torr 1 atm L = 101.325 J 1 m^3 = 1000 L 1 pm = 10^{-12} m

1 atm = 760 mmHg $0^oC = 273.15$ K 1 amu = 1.6605×10^{-27} kg

Key Equations:

$PV = nRT$ $(P + an^2/V^2)(V - nb) = nRT$ $w = -P_{ext}\,\Delta V$ $q = C\,\Delta T$ $\Delta U = q + w$

$H = U + PV$ $\Delta H = \Delta U + \Delta n\,RT$ $c = \lambda\nu$ $\lambda = h/p$ $p = mv$

$\Delta x\,\Delta p \geq h/(4\pi)$ $E = h\nu$ $E_n = -R_H/n^2$ $\mu = \delta r$ B.O. $= \frac{1}{2}(n_b - n_a)$