The Chemistry 151 Companion

Lab Manual, Problem Sets, Lecture Slides and Learning Resources

Dr. Michael A. Russell
Mt. Hood Community College
Summer 2025

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Welcome to Chemistry 151!

My name is **Dr. Michael Russell** and I am pleased that you have decided to take Chemistry 151 with me this quarter. I look forward to an exciting term with you!

Here are some hints on how to get the most out of the ***Chemistry 151 Companion***:

- Glance over the **Table of Contents** that follows this introduction. The Table of Contents lists the respective page numbers for each of the sections.

- Information on **how to construct a graph** can be found in the lab section (with a Roman number "***I***" leading.) A handy **pictorial guide to common glassware**, a ScienceNotes.org **Periodic Table** and a **parts per thousand handout** follow shortly afterwards. The **labs** we will be performing this quarter follow.

- The **problem sets** that we will use this quarter follow the lab section. They are listed with a Roman number "***II***".

- A printed version of the **Lecture slides** that will be covered this quarter can be found next. The PowerPoint notes use a Roman number "***III***" followed by the Chapter number, then the page number. For example, ***Page III-6-3*** would refer to a PowerPoint note (the "***III***") in Chapter ***6*** (the "***6***"), and the "***3***" refers to the ***third*** page of notes for Chapter 6.

- **Learning Resources** follow the lecture slides and augment difficult concepts discussed in lecture. The numbering system is similar to the PowerPoint slides system but with a "**IV**". For example, if you see ***Page IV-5-1*** this would refer to a Learning Resource handout (the "***IV***") in Chapter ***5*** (the "***5***"), and the "***1***" refers to the ***first*** page of lecture handouts for Chapter 5.

- Finally, **sample quizzes and exams** (with answers, they start with a Roman number **V**) follow. Note that additional quiz and exam testing resources are available on the CH 151 website (http://mhchem.org/151).

If you have questions throughout the quarter, please do not hesitate to contact me using the contact information below. Good luck with your studying!

Peace,

Dr. Michael Russell
mike.russell@mhcc.edu - *email address*
http://mhchem.org/151 - *CH 151 website*
(503) 491-7348 - *phone*
AC 2568 - *office*

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CHEMISTRY 151 TABLE OF CONTENTS

All of these materials can be found on the Chemistry 151 website (http://mhchem.org/151)

CH 151 Laboratory Experiments

CH 151 Labs

CH 151 Problem Sets

CH 151 Lecture Slides

CH 151 Learning Resources

CH 151 Sample Quizzes and Exam *(with answers)*

More learning resources can be found on the CH 151 website: ***http://mhchem.org/151***

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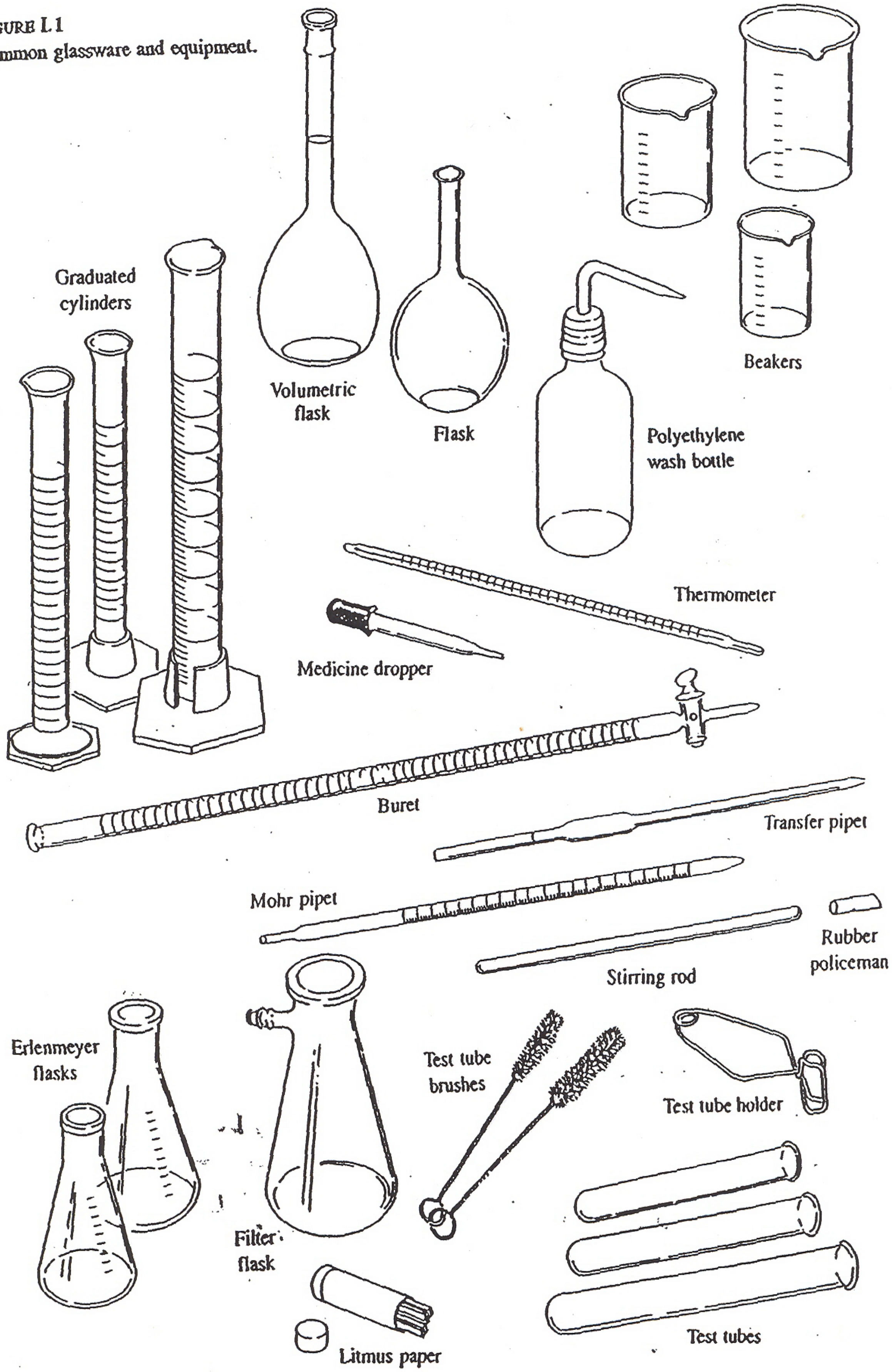
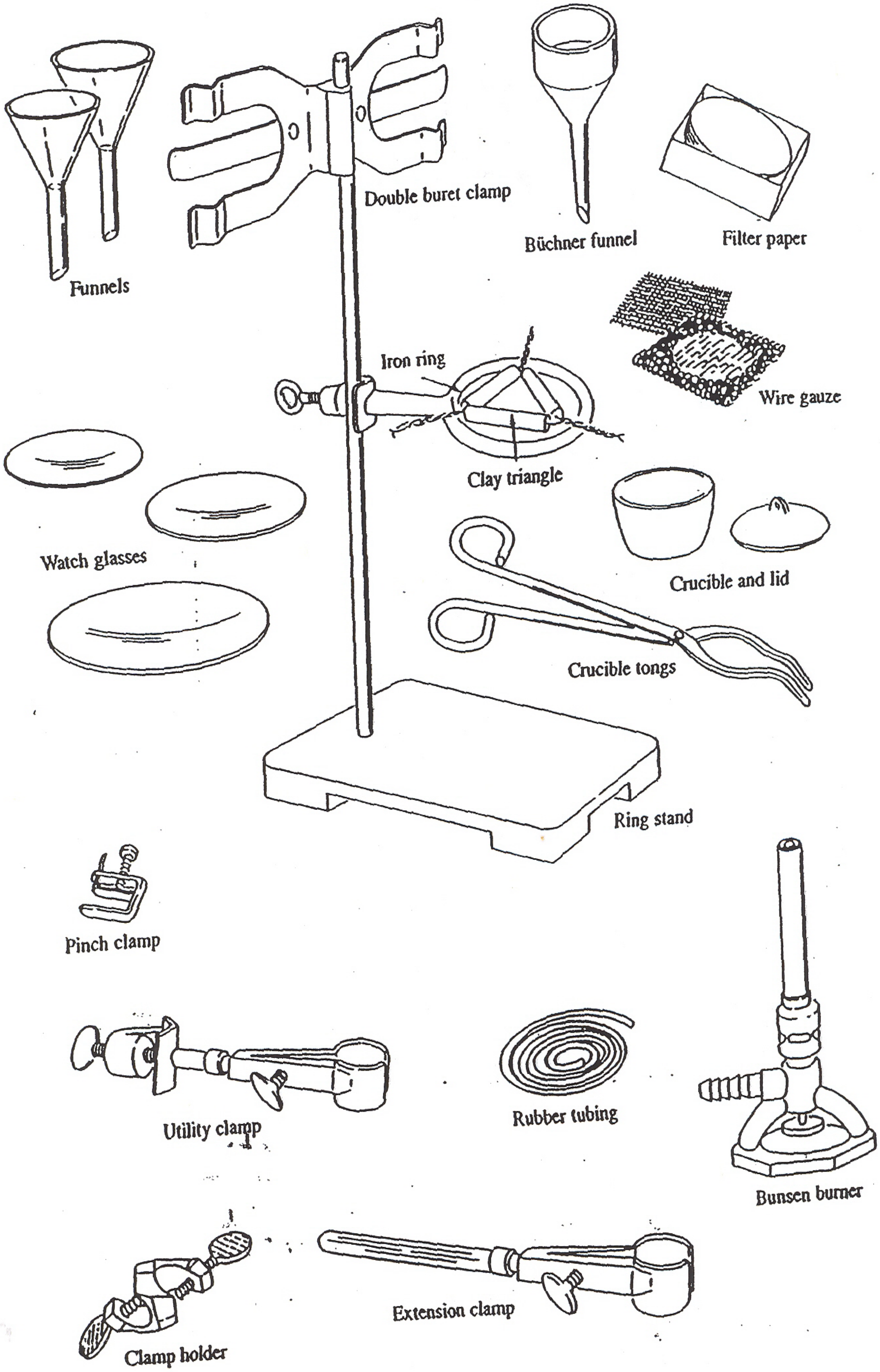
FIGURE I.1
Common glassware and equipment.




Funnels
Double buret clamp
Büchner funnel
Filter paper
Iron ring
Wire gauze
Clay triangle
Watch glasses
Crucible and lid
Crucible tongs
Ring stand
Pinch clamp
Utility clamp
Rubber tubing
Bunsen burner
Extension clamp
Clamp holder

Laboratory Safety & Etiquette

Safety is of utmost importance. Work in the laboratory should be a safe experience. It will be safe, however, only if certain safety precautions are followed without exception. Safety is up to you. Everyone working in the chemistry laboratories must follow the following rules. Your instructor will discuss specific safety precautions relevant to each experiment during the pre-lab lecture. Do not hesitate to consult with your instructor if you have questions regarding any safety precautions. Failure to observe laboratory safety rules and procedures may result in injury to you or to fellow students. Students who do not follow these safety rules (including proper attire) will be asked to leave the laboratory. Repeat offenders may be dropped from the course at the discretion of the instructor.

1. **Appropriate attire:** Appropriate protective clothing must be worn at all times while in the laboratory. It is a good idea not to wear your best clothing to lab since many chemicals can stain, bleach or generate holes in your clothing.
    a. **Safety goggles** approved by the chemistry department must be worn at all times, even if you are wearing prescription glasses. Contact lenses are not recommended in the lab. Various fumes may accumulate under the lenses and injure your eyes. You are responsible for bringing your own pair of safety goggles to lab each week. Students who borrow safety goggles from the instructor will have points deducted from their lab. Students who fail to wear their safety goggles will be reminded once and have points deducted. The second time a student is seen without safety goggles on during a lab period, the student will be asked to leave the laboratory.
    b. **Shirts** must cover the entire upper torso, including the midsection and upper chest area and should be long enough to tuck inside your pants. Cotton t-shirts are fine. Tank tops, scooped neck tops, leotards, sleeveless blouses and tops made of sheer material are not allowed.
    c. **Pants and skirts** must be at least knee length.
    d. **Shoes** must be flat-soled and cover the entire foot. Socks must be worn with shoes. Sandals, open-toe shoes and high heels are not permitted.
    e. **Long hair** (shoulder length and longer) and billowy clothing must be tied back while working in the lab.

2. **Food and Drink:** NO food or drink will be allowed in the laboratory. This includes coffee, water, candy and chewing gum.

3. Working in the laboratory without an instructor present is strictly forbidden. Students must work in instructional laboratories only during regularly scheduled lab periods and then only when supervised by a member of the faculty.

4. Do not perform any unauthorized experiments. If you have an idea for improving an experiment or for a new experiment, consult with your instructor.

5. Wash your hands after every experiment and each time your hands come in contact with chemicals.

6. **Scales:** Never weigh reagents or chemicals directly on a balance or scales. First weigh an empty container or weighing paper, then press tare or "re-zero" to set the mass reading to zero. Then add your reagent to the container or weighing paper and re-weigh. Balances are expensive! Clean any spills immediately! Replace caps on bottles and return to cart when complete.

7. **Fume hoods** should be used when performing experiments that generate an objectionable gas.

8. **Working With Chemicals:**
    a. Never smell or taste anything in the laboratory unless specifically directed by your instructor. Many chemicals are poisons. Use your hand to waft the odor to your nose.
    b. Always **read the label** on all chemical bottles and waste bottles. If you see the wrong chemical, you may have a serious explosion. If unsure, consult with your instructor.
    c. Do not take chemical bottles to your lab bench unless directed by your instructor. Pour the approximate amount you need from the bottle into a small container and take this to your bench.
    d. Always use a metal spatula or scoopula to transfer solid chemicals. Do not use your finger to transfer chemicals. This will directly expose you to the potential hazards of the chemical and might contaminate the remaining chemical in the container.
    e. Do not put excess reagent back into the original bottle. There is always a chance of contaminating the original sample. Ask your instructor how to properly dispose of excess chemicals.
    f. Do not put pipets directly in any reagent bottle. This might result in contamination of the remaining liquid in the bottle. Never mouth pipet any liquid in the lab.
    g. Keep the lids and caps on the chemical bottles. Put the lids back on as soon as you are finished dispensing the material. Many chemicals are sensitive to light or to moisture in the air.
    h. When diluting concentrated acids or bases, add the acid or base slowly into water. Never pour water into acid. The heat generated from adding water to a concentrated acid or base solution can cause the solution to splatter or shatter the glass.

9. **Waste:** Dispose chemical waste in designated containers. Only flush chemicals down the sink if instructed by your instructor. Never pour organic waste down the drain. The waste containers are in the hood for each experiment. Read labels on waste containers to be sure to dispose of waste in the proper container. Disposing waste in the wrong container can generate an unwanted (and unexpected) chemical reaction!

10. **Spills:** Clean up any spills immediately and dispose of the spilled material properly. Check with your instructor on the proper way to clean up any material that you spill.

11. **Chipped or broken glassware** should be thrown in the glass waste container. Report broken glassware to your instructor so that it can be replaced.

12. **Hot objects** will burn! Do not pick up hot objects with your fingers. Use tongs or hot pads. Hot glass will crack if run under cold water. Allow heated glass sufficient time to cool.

13. **Accidents and Emergencies:** Report all injuries and accidents, no matter how minor, to your instructor immediately. Know the location of the fire extinguishes, fire blankets, safety showers, and eyewash stations. Familiarize yourself with two different exits from the lab, in the event of an emergency situation. Accidents are usually minor, but it is best to be prepared for serious trouble.

14. **Be aware of your classmates!** Are they obeying the safety rules? A nearby accident may not hurt or harm him/her but may injure you!

15. Above all else, **ask the instructor if you have any safety related questions!**

Summer 2025 Chemistry 151 *with* Dr. Michael A. Russell

CH 151, Mt. Hood Community College, Gresham, Oregon, USA 97030

Office: **AC 2568** *Phone:* **(503) 491-7348** *(no texts)*

Email: **mike.russell@mhcc.edu** *or* **mike.russell@mhchem.org**

Office Hours: Held in person MTW 7:30 - 8 AM

Chemistry 151 website:
http://mhchem.org/151

***Required/Recommended Materials**:*

- *Textbook:* **"Chemistry: Atoms First 2e"** *by* The OpenStax College *and* remixed *by the instructor, available here for **free**:* **http://mhchem.org/text/OpenStaxAtomsRussell.pdf**
- *The* **Chemistry 151 Companion**, *purchase here:* **http://mhcc.edu/bookstore**
- **Calculator** with at least EXP or EE *(such as the TI-83, TI-89, etc.)*
- *Safety goggles*

Course Description: CH 151 is a basic course designed for students who want to take the CH 221/222/223 sequence but lack sufficient math and/or chemistry background. This one-term course includes mathematical applications appropriate for the first term of the above chemistry sequence, as well as an introduction to classification of matter, atomic theory, stoichiometry and nomenclature. **Prerequisite**: RD090, WR090, each with a grade of "C" or better; or placement above levels. **Co-requisite**: MTH 095 or higher.

Course Philosophy: To be successful, students enrolled in this summer accelerated chemistry course should complete all assignments before coming to class, attend classes regularly, participate in discussions, and think critically to discover the fundamental theories inherent to this course. All homework assignments represent the *minimum* requirement for understanding the principles of chemistry. It is assumed that A and B students will perform enough *unassigned* exercises to master the concepts.

I encourage questions in this class. If you contact me by email, I will respond to you normally within 24 hours..

The Honor Principle: All students will be expected to behave with the highest moral and academic integrity while enrolled in this class. Plagiarism, cheating or sharing information on tests or laboratory reports, disruptive behavior, and other related offenses will be dealt with according to the directives stated in the current *Mt. Hood Community College Student Guide*. Offering, asking for, giving or receiving help from a person or website without instructor consent is cheating. Copying and/or sharing any course materials outside this class is not allowed and illegal due to copyright laws.

Grading:	Problem sets (4 total)	40 points	*6.7%*
	Quizzes (4 total, 20 points each)	80 points	*13.3%*
	Seven lab experiments (20 points each)	140 points	*23.3%*
	Midterm Exam	140 points	*23.3% of total points*
	Final Exam	200 points	*33.3%*
	Total points:	**600** points	***100%** (99.9%)*

Tentative grading distribution: **A**: 90-100% **B**: 80-89% **C**: 65-79% **D**: 50-64% **F**: less than 50%

Exams and Quizzes will be completed exclusively in class. Assignments must be submitted in person to avoid a point penalty.

Labs and Problem Sets will be submitted on campus and in class. Late Assignments will suffer a point penalty.

"What's Due This Week" Schedule for Chemistry 151

***Assignments** (problem sets, labs, etc.) can be found on the **Chemistry 151 website** (http://mhchem.org/151)*
*and in the **Chemistry 151 Companion**.*

Students must bring a printed copy of the lab on the specified day, then turn it in on the deadline during class at 8 AM. Problem sets will be turned in during class in AC 2501 at 8 AM on the specified date; **quizzes and exams will be completed during class time**. Emailed assignments will incur a point fee.

*The **textbook** for this class is **free** and **available here**:* http://mhchem.org/text/OpenStaxAtomsRussell.pdf

Week	Dates	Assignment
1	6/23	*Introduction* to the course, *Lecture* - Chapter 1 *Lab #1:* Eight Bottles *due Tuesday, June 24 at 8 AM*
	6/24	*Lecture:* Chapter 1 and/or Chapter 2.1 - 2.3 (isotopes, atomic number, the periodic table) *Lab #2:* Problem Solving *due Monday, June 30 at 8 AM*
	6/25	*Due:* Problem Set #1 *Chapter 1* *Take:* Quiz #1: *Conversions, Significant Figures, the Metric System, etc.* *Lecture:* Chapter 4.3 (Nomenclature)
2	6/30	*Lecture:* Chapter 2.4 (gram/mole/atom manipulations) *Lab #3:* Nomenclature *due Tuesday, July 1 at 8 AM*
	7/1	Lecture catch-up / gram/mol/atom review *Lab #4:* Density *due Monday, July 7 at 8 AM*
	7/2	*Due:* Problem Set #2 *Chapter 2.1 - 2.4 and Chapter 4.3* *Take:* Quiz #2: *Chemical History, Isotopes, Nomenclature, etc.* Review *for the Midterm Exam*
3	7/7	**Midterm Exam** *(covers Chapters 1, 2.1-2.4, 4.3) – bring calculator, pencil, no make up if missed* *Lecture:* Chapter 7.1 (Balancing Chemical Equations)
	7/8	*Lecture:* Chapter 4.4 - 4.6 (Lewis Structures / VSEPR) *Lab #5:* Chemical Equations & Reaction Types *due Wednesday, July 9 at 8 AM*
	7/9	*Due:* Problem Set #3 *Chapter 7.1 only* *Take:* Quiz #3: *Balancing Chemical Equations, Types of Reactions* *Lab #6:* Chemical Models *due Monday, July 14 at 8 AM*
4	7/14	*Lecture:* Chapter 3.3 - 3.5 (Atomic Orbitals and Electrons) *Lab #7:* Percent Potassium Chlorate *due Tuesday, July 15 at 8 AM - goggles required*
	7/15	*Due:* Problem Set #4 *Chapter 4.4 - 4.6 and Chapter 3.3 - 3.5* *Take:* Quiz #4: *Lewis Structures / VSEPR and Electron Configurations* Review *for the Final Exam*
	7/16	**FINAL EXAM** - *covers all chapters, no make up if missed, bring calculator and pencil*

Getting Started in Chemistry 151

Welcome to Chemistry 151! I am glad to have you enrolled in CH 151! Here are some hints on how to get started in the class:

- First, **know that I am here to help you succeed in this class**. If you have any questions, please email me (mike.russell@mhcc.edu). I try to respond to student inquiries within 24 hours.

- **Office hours will be held in AC 2568** (MTW at 7:30 AM) for the duration of this class.

- **Purchase the Chemistry 151 Companion from the MHCC Bookstore (http://mhcc.edu/bookstore)**. You will need printed materials this quarter, and purchasing the Companion keeps you from printing them all yourself.

- The **Chemistry 151 Textbook** is **free** and **legal to download** from our website:
  http://mhchem.org/text/OpenStaxAtoms_Russell.pdf

- The **"What's Due This Week" Schedule for CH 151** located on page 2 of your syllabus **lists all the problem set due dates, assignment deadlines, labs performed, exam/quiz dates, and related information for this term**. You can plan your term by referencing this handout.... follow it closely and you will do well in CH 151!

- **Check your email often during Chemistry 151**. I will be sending weekly reminders as to "what is due this week" in CH 151. If you would prefer that I use a non-saints email address to communicate with you, let me know - this is easy to set up!

- The **Chemistry 151 website** is worth exploring. The Chemistry 151 website has a host of learning opportunities waiting for you. You can download and/or print copies of the syllabus, problem sets, quizzes and exams, labs, quiz answers, and more. The website is:
  http://mhchem.org/151

- You can **download** the entire **Microsoft Office** suite of programs (Word, Excel, PowerPoint, etc.) **for free**… see this link for information: **https://mhcc.edu/OfficeInstall/**

Again, welcome to Chemistry 151! Let me know if I can make your learning experience better in any way, and I look forward to working with you this term!

Peace, Dr. Michael Russell (mike.russell@mhcc.edu, 503.491.7348, AC 2568)

Periodic table from ScienceNotes.org

Periodic Table of the Elements

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 **H** Hydrogen 1.008																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012											5 **B** Boron 10.811	6 **C** Carbon 12.011	7 **N** Nitrogen 14.007	8 **O** Oxygen 15.999	9 **F** Fluorine 18.998	10 **Ne** Neon 20.180
11 **Na** Sodium 22.990	12 **Mg** Magnesium 24.305											13 **Al** Aluminum 26.982	14 **Si** Silicon 28.086	15 **P** Phosphorus 30.974	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.948
19 **K** Potassium 39.098	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.956	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.942	24 **Cr** Chromium 51.996	25 **Mn** Manganese 54.938	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933	28 **Ni** Nickel 58.693	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.631	33 **As** Arsenic 74.922	34 **Se** Selenium 78.971	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.798
37 **Rb** Rubidium 85.468	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.906	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.906	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium 98.907	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.906	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.868	48 **Cd** Cadmium 112.414	49 **In** Indium 114.818	50 **Sn** Tin 118.711	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.6	53 **I** Iodine 126.904	54 **Xe** Xenon 131.294
55 **Cs** Cesium 132.905	56 **Ba** Barium 137.328	57-71	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.948	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.085	79 **Au** Gold 196.967	80 **Hg** Mercury 200.592	81 **Tl** Thallium 204.383	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.980	84 **Po** Polonium [208.982]	85 **At** Astatine 209.987	86 **Rn** Radon 222.018
87 **Fr** Francium 223.020	88 **Ra** Radium 226.025	89-103	104 **Rf** Rutherfordium [261]	105 **Db** Dubnium [262]	106 **Sg** Seaborgium [266]	107 **Bh** Bohrium [264]	108 **Hs** Hassium [269]	109 **Mt** Meitnerium [278]	110 **Ds** Darmstadtium [281]	111 **Rg** Roentgenium [280]	112 **Cn** Copernicium [285]	113 **Nh** Nihonium [286]	114 **Fl** Flerovium [289]	115 **Mc** Moscovium [289]	116 **Lv** Livermorium [293]	117 **Ts** Tennessine [294]	118 **Og** Oganesson [294]

Lanthanide Series	57 **La** Lanthanum 138.905	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.908	60 **Nd** Neodymium 144.243	61 **Pm** Promethium 144.913	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.925	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.930	68 **Er** Erbium 167.259	69 **Tm** Thulium 168.934	70 **Yb** Ytterbium 173.055	71 **Lu** Lutetium 174.967
Actinide Series	89 **Ac** Actinium 227.028	90 **Th** Thorium 232.038	91 **Pa** Protactinium 231.036	92 **U** Uranium 238.029	93 **Np** Neptunium 237.048	94 **Pu** Plutonium 244.064	95 **Am** Americium 243.061	96 **Cm** Curium 247.070	97 **Bk** Berkelium 247.070	98 **Cf** Californium 251.080	99 **Es** Einsteinium [254]	100 **Fm** Fermium 257.095	101 **Md** Mendelevium 258.1	102 **No** Nobelium 259.101	103 **Lr** Lawrencium [262]

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CH 151 Summer 2025:

"Eight Bottles" ***Lab*** **-** *Instructions*

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-1-3 through I-1-6 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/t/1.htm**

The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.

Step Three:

Bring the printed copy of the lab with you on Monday, June 23. During lab, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in** (pages I-1-5 through I-1-6 *only* to avoid a point penalty) **at 8 AM on Tuesday, June 24.** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor. Good luck on this assignment!

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Eight Bottles

An Introduction to Scientific Investigations

INTRODUCTION

Problem solving is not restricted to scientific investigations. Indeed, it is a life long process that involves every aspect of human endeavor. The way one solves a problem is related to one's individual learning style. There are, however, some common factors which seem to be part of most scientific investigations. Although, every investigator, being human, approaches each problem with some preconceived ideas, facts are gathered by accurate observation of behavior of the system of interest. Conclusions are based solely on the observed data.

Only by using experimental observations to study the behavior of matter, arranging the results of such studies in an orderly fashions, correlating the observed data and testing these correlations (theories or hypothesis) by further systematic observations can one hope to increase our ability to deal with the physical world around us. This approach is usually referred to as the Scientific Method. There is nothing unique about the order of activity to this method other than it provides a logical way to deduce order and causality for natural phenomena. An inherent part of the scientific method is the element of creativity. This is what makes possible the development of completely new concepts. This experiment is designed to allow you to use some of the elements of scientific investigation mentioned here.

Eight bottles, labeled A through H, containing eight different solutions have been prepared for your examination. When mixed together, in pairs, several of these solutions will undergo a chemical reaction. A reaction can be observed by one of the following changes:

1. A color change will occur.
2. A gas will be evolved (bubbles will be observed)
3. A precipitate (a cloudy mixture) will form.
4. The evolution of heat.

Be carefully observing any changes that occur it should be possible for you obtain enough data to characterize each of these solutions. In this experiment we will use only a color change or a precipitate to detect a chemical reaction. From the results of your study, you should then be able to prepare a concise description of how to identify the contents of an unlabeled bottle assuming the others are available for mixing.

PROCEDURE

Obtain a tray with dropper bottles containing solutions labeled A-H. In each dimple of a spot plate, combine 3 drops each of various combinations of two solutions. Mix with a clean stirring rod, and record your observations (**color change or precipitate formation along with the color of the precipitate**) in the data table provided. When the spot plate is full, simply rinse it off with distilled water into the waste container and continue experimenting.

Obtain two unknown solutions from your instructor and record their ID #s on your data sheet. Experiment with these unknown by mixing with the contents of each of the bottles labeled A-H. Remember to mix only two solutions at a time. Record your observations on the data sheet.

From the data recorded in your data table, determine the identity of your unknowns (one of the solutions A-H)

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Eight Bottles

<u>DATA</u>

NAME:
Lab Partner(s):
*Include **all** first and last names for full credit!*

Solutions	A	B	C	D	E	F	G	H
A								
B								
C								
D								
E								
F								
G								
H								
Unknown Number								
Unknown Number								

CONCLUSIONS:

Based upon your observations, describe how you would identify an unknown solution containing one of these eight solutions (A-H). Be careful with your wording. Your answer should make sense to someone who has not performed the experiment.

1. Why do you obtain the maximum useful information about the solutions by mixing only two solutions at a time?

2. How would you detect the evolution of a gas upon mixing the solutions?

3. Which of the A-H "solution(s)" could be distilled water? How do you know?

Unknown number __________ Identity (letter) __________

Unknown number __________ Identity (letter) __________

CH 151 Summer 2025:

“Problem Solving” ***Lab -***

Instructions

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-2-3 through I-2-8 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/t/2.htm**

The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.

Step Three:

Bring the printed copy of the lab with you on Tuesday, June 24. During lab in, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in** (pages I-2-5 through I-2-8 *only* to avoid a point penalty) **at 8 AM on Monday, June 30.** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor. Good luck on this assignment!

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Problem Solving

Dimensional analysis, also known as the **factor-label method**, is a problem solving technique using units (labels) and conversion factors. **Units** tell us the type of measurement being made; for example, "5.2 cm" has a unit (cm) which tells us the measurement to be made is length. **Conversion factors** (also known as "equalities") are fractions that relate two kinds of units; for example, "6.0 cm / s" tells us that for every 1 second that passes (time), 6.0 cm are covered (length). Notice that "6.0 cm s^{-1}" is the same as "6.0 cm / s" in unit notation.

Most problems ask a question whose <u>answer</u> is a number with its unit. Problems also give <u>information</u> that contains numbers with their units. Multiply the information by conversion factors so that all units cancel *except* the units needed in the answer. (A unit in the numerator may be cancelled by placing the same unit in the denominator of the neighboring conversion factor. Conversely, a unit in the denominator may be cancelled by placing the same unit in the numerator of the neighboring conversion factor.)

- Numbers and units are considered separately.
- Multiply by as many conversion factors as necessary.
- Common conversion factors may or may not be supplied with the problem.

<u>Examples</u>:

1. How many hours are in 6 days?

$$6 \text{ days} * \frac{24 \text{ hours}}{1 \text{ day}} = 144 \text{ hours}$$

2. How many seconds are in 5 hours?

$$5 \text{ hours} * \frac{60 \text{ minutes}}{1 \text{ hour}} * \frac{60 \text{ seconds}}{1 \text{ minute}} = 18,000 \text{ seconds}$$

3. How many feet per second is 5 miles per hour?

$$\frac{5 \text{ miles}}{1 \text{ hour}} * \frac{1 \text{ hours}}{60 \text{ minutes}} * \frac{1 \text{ minute}}{60 \text{ seconds}} * \frac{5280 \text{ feet}}{1 \text{ mile}} = 7.3 \ \frac{\text{feet}}{\text{second}}$$

A common **variation** occurs when more than one piece of information is provided with the problem. In these cases, start with the information that contains the same type of units as the answer. (For example, if length units are needed in the numerator of the answer, use the information that contains length units and arrange it so that those length units are in the numerator.) Next, multiply by conversion factors so that unwanted units cancel.

<u>Test Yourself</u>:

1. How many gallons of milk does a family drink in 5 days if they drink 4 pints per day? *Answer:* 2.5 gallons
2. How many minutes will it take an automobile traveling 60 miles per hour to travel a distance of 400 miles? *Answer:* 400 minutes

Using Scientific Notation

Scientific Notation is used by scientists to express very large and very small numbers in a compact fashion.

To express a number in scientific notation, we rewrite the quantity as a number (between 1 and 10) times 10 raised to a power (exponent) that tells us how we moved the decimal point.

- Multiply the number by 10^0 ($10^0 = 1$)
- Move the decimal point to give a number between 1 and 10
- Every time we shift the decimal point to the <u>left</u> by one place we <u>increase</u> the value of the exponent by one
- Every time we shift the decimal point to the <u>right</u> by one place we <u>reduce</u> the value of the exponent by one

<u>Example</u>: Write 120,000 in scientific notation.

$$120{,}000 = 120{,}000 * 10^0 = 1.2 * 10^5$$

<u>Example</u>: Write 0.0000012 in scientific notation.

$$0.0000012 = 0.0000012 * 10^0 = 1.2 * 10^{-6}$$

To express a number that is written in scientific notation as a non-exponential quantity:

- Move the decimal point the same number of places as the value of the exponent and eliminate the exponential part of the number.
- If the exponent is <u>positive</u>, we move the decimal to the <u>right</u> to the same number of places as the value of the exponent. The result should be a number *greater than* 1 ***unless*** the original number is negative.
- If the exponent is <u>negative</u>, we move the decimal to the <u>left</u> to the same number of places as the value of the exponent. The result should be a number *less than* 1 ***unless*** the original number is negative.

<u>Example</u>: Write $1.23 * 10^6$ in non-exponential form.

$$1.23 * 10^6 = 1{,}230{,}000$$

<u>Example</u>: Write $1.11 * 10^{-5}$ in non-exponential form.

$$1.11 * 10^{-5} = 0.0000111$$

PROBLEM SOLVING Lab **Name:**

first and last name

Directions: Use this form to complete this assignment. Show all work in a neat and orderly fashion using the dimensional analysis method. Underline or box your final answer with the correct significant figures and units. Use scientific notation if appropriate.

Helpful Conversion Factors:

Mass:	453.6 g = 1 lb, and 28.34 g = 1 ounce
Volume (wet):	0.9464 L = 1 qt = 2 pints
	1 gallon = 3.7856 L = 4 qt = 128 fluid ounces
	1 mL = 1 cm^3
Distance:	2.54 cm = 1 in (exact)
	1.609 km = 1 mile
	12 inches = 1 foot (exact)

---

1. A piece of copper weighs 17.62 lb. What is the weight in kg?

2. The average female has 4500 mL of blood. What is this volume in gallons?

3. The distance from the earth to the moon is 3.9×10^5 km. What is the distance in feet?

4. The fastest pitch in major league baseball was thrown at 100.8 miles per hour. What was the speed in meters per sec?

5. The human heart pumps blood at the rate of 6.8 fl oz/sec. How many gal/hr does the heart pump? (Note: Ounces and fluid ounces are not the same units)

6. What is the water capacity in cubic meters of a rectangular swimming pool, dimensions: 12.0 ft long; 6.00 ft wide; 8.00 ft deep?

7. Osmium is the densest metal. What is its density (g/cm^3) if 50.00 g occupies 2.22 cc? (1 cc = 1 mL)

8. If your blood has an average density of 1.05 g/mL at 20 ˚C, how many pounds of blood do you lose when you donate 1.0 pint of blood?

9. The density of ethanol is 0.789 g/mL. How many quarts would 5.00 lbs occupy?

10. How many pints is exactly one pound of table salt (density = 2.16 g/cm^3)?

11. Milk is pasteurized at 145 ˚F. What is this in ˚C? In Kelvin?

12. An oven to cook pizza is set at 275 ˚C. What is this in ˚F? Kelvin?

13. If a bumblebee weighs 0.0022 kg, how many bees weigh 5.0 lb?

14. A copper alloy is found to be 38.7% copper by mass. How many kilograms of copper are present in a 30.2 pound sample?

15. A cylindrical rod of copper is 3.21 inches long and has a diameter of 3.2 in. What is the mass in ounces? The density of copper is 8.93 g/cm^3. [Hint: Find volume of cylinder first! $V = \pi r^2 L$]

16. Metric conversions: **All answers must be in correct scientific notation**. Helpful metric prefixes and conversions: micro (μ, 10^{-6}), nano (n, 10^{-9}), pico (p, 10^{-12}), femto (f, 10^{-15}), Mega (M, 10^{6})

6.50 m = ___________ cm
33 kg = ____________ mg
43 mg = _____________ g
22.5 mm = _________ nm

7.25 cm = ___________ km
4.39 pg = ____________ mg
62 μL = ____________ dL
7.6 cm = ____________ nm

413 ng = _________ mg
23.1 cm = ________Mm
6.3 fm = _________ cm
352 kg = _________ dg

Metric examples on next page!

Prefix	Base	Symbol	Acronym	Example with mass
kilo	10^3	k	*kiss*	kilogram, kg
hecto	10^2	h	*him/her*	hectogram, hg
deka	10^1	da	*dearly*	dekagram, dag
base	10^0	base	*but*	gram, g
deci	10^{-1}	d	*don't*	decigram, dg
centi	10^{-2}	c	*call*	centigram, cg
milli	10^{-3}	m	*me*	milligram, mg

Also: **micro (µ) = 10^{-6}** *and* **nano (n) = 10^{-9}**

Example: There are 10^3 grams in one kilogram,
or there are 10^{-3} kilograms in one gram

Example: There are 10^{-2} grams in one centigram,
or there are 10^2 centigrams in one gram

Example: There are 10^2 liters in one hectoliter,
or there are $(10^{-2}\ \mathrm{hL/L})(10^{-2}\ \mathrm{L/cL}) = 10^{-4}\ \mathrm{hL} / \mathrm{cL}$

CH 151 Summer 2025:

"Nomenclature" ***Lab*** **-** *Instructions*

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-3-3 through I-3-8 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/t/3.htm**

The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.

Step Three:

Bring the printed copy of the lab with you on Monday, June 30. During lab, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in (**pages I-3-5 through I-3-8 *only* to avoid a point penalty**) at 8 AM on Tuesday, July 1.** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor. Good luck on this assignment!

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Nomenclature: The Language of Chemistry

Systematic chemical names of inorganic compounds were developed by a group of scientists who were part of the International Union of Pure and Applied Chemistry (IUPAC) which first met in 1921. Elements are represented by symbols which are the first, first two, or first and third letters from the name of the element. There are some notable exceptions, where the symbols appear to have no connection to the name of the element. These symbols are derived from early names for these elements. The table below illustrates some of these.

Present Name	Symbol	Former Name
Antimony	Sb	Stibium
Copper	Cu	Cuprum
Gold	Au	Aurum
Iron	Fe	Ferrum
Lead	Pb	Plumbum
Potassium	K	Kalium
Silver	Ag	Argentum
Sodium	Na	Natrium
Tin	Sn	Stanum
Tungsten	W	Wolfram

The names of inorganic compounds are constructed so that every compound can be named from its formula and each formula has a name unique to that formula. For the purpose of clarity, we will divide the formulas into the following categories:

1) Binary compounds of nonmetals (covalent molecules)
2) Binary compounds of a metal and nonmetal (ionic compounds)
3) Ternary and higher compounds (polyatomic ions and acids)

I. Binary Covalent Compounds: two nonmetals

1. Name first element, preceded by Greek prefix for number of atoms. If one, omit mono.
2. Name the second element, preceded by Greek prefix for number of atoms even if one.

The ending of the second element is -ide.

Greek Prefixes:
1 = mono, 2 = di, 3 = tri, 4 = tetra, 5 = penta
6 = hexa, 7 = hepta, 8 = octa, 9 = nona, 10 = deca

Examples:

Formula	Name
PCl_3	Phosphorous trichloride
SO_2	Sulfur dioxide
CO	Carbon monoxide
N_2O	Dinitrogen monoxide

II. Ionic Compounds: metal + nonmetal - A. Metal with a fixed charge

1. Name metal (cation) first - **only** for metals in Groups IA, IIA and the "stairs"
2. Name nonmetal (anion) with the ending changed to -ide. Charge = **group number - 8**

Ex:	Formula	Name	**Fixed Charge Cations**
	KCl	Potassium chloride	IA = +1
	Na_2S	Sodium sulfide	IIA = +2
	Al_2S_3	Aluminum sulfide	IIIA = +3 one of the 'stairs' (*video*)

In ionic compounds, the metal and nonmetal must combine in a ratio to give an overall neutral charge. To write formulas based on name, first write the symbol with the correct charge for the cation and anion. Then determine the lowest ratio for a neutral compound.

B. Metals with variable charge (transition metals, lanthanides, actinides, etc.)

1. Name metal. In parentheses write the charge of the metal in Roman numerals.
   The charge is determined based on the fixed charge of the nonmetal.
   [Fixed charges of nonmetal: VIIA = -1; VIA = -2; VA = -3]
2. Name nonmetal with the ending -ide. Charge = **group number - 8**

Examples:	Formula	Name	Old Method – ***do NOT use!***
	CuCl	Copper(I) chloride	*Cuprous chloride*
	$CuCl_2$	Copper(II) chloride	*Cupric chloride*
	FeO	Iron(II) oxide	*Ferrous oxide*
	Fe_2O_3	Iron(III) oxide	*Ferric oxide*

III. Polyatomic Anions and Acids

When writing names of ionic compounds composed of polyatomic anions or of acids, you must first learn the name, number of oxygens, and charge of the most common polyatomics (listed below). Then add the following rules for naming polyatomics and acids with differing number of oxygens. Notice that as oxygens are added/ subtracted, the polyatomic charge remains the same. **Common polyatomic ions** include:

CO_3^{2-}	carbonate	ClO_3^{1-}	chlorate	OH^{1-}	hydroxide
NO_3^{1-}	nitrate	BrO_3^{1-}	bromate	NH_4^{1+}	ammonium
PO_4^{3-}	phosphate	IO_3^{1-}	iodate	HCO_3^{1-}	hydrogen carbonate
SO_4^{2-}	sulfate	MnO_4^{1-}	permanganate	$Cr_2O_7^{2-}$	dichromate

$C_2H_3O_2^{1-}$ - acetate

# Oxygens	***Anion***	***Example***	***Acid***	***Example***
+1 Oxygen	per-ate	perchlorate, ClO_4^{1-}	per-ic	perchloric acid, $HClO_4$
common	-ate	chlorate, ClO_3^{-1-}	-ic	chloric acid, $HClO_3$
-1 Oxygen	-ite	chlorite, ClO_2^{1-}	-ous	chlorous acid, $HClO_2$
-2 Oxygen	hypo-ite	hypochlorite, ClO^{1-}	hypo-ous	hypochlorous acid, HClO
No Oxygen	-ide	chloride, Cl^{1-}	hydro-ic	hydrochloric acid, HCl

For more polyatomic / acid help, see the "**Common Polyatomic Ions and the Corresponding Acids**" handout in your *Companion* under "Learning Resources."

Nomenclature Lab

Name:
first and last name

1a. Ionic Compounds (metal + nonmetal)

	FORMULA	**CATION**	**ANION**	**NAME**
Ex.	$CaBr_2$	Ca^{2+}	Br^{1-}	Calcium bromide
1				**Magnesium nitride**
2		$\mathbf{K^{+}}$	$\mathbf{S^{2-}}$	
3	$\mathbf{ZnO}$			
4		$\mathbf{Sn^{4+}}$	$\mathbf{O^{2-}}$	
5	$\mathbf{Cr_2S_3}$			
6				**Copper(I) phosphide**
7	$\mathbf{RbI}$			
8				**Calcium nitride**
9				**Titanium(IV) chloride**
10	$\mathbf{SrS}$			
11	$\mathbf{Au_2O_3}$			
12				**Cadmium phosphide**

1b. Covalent Compounds (nonmetal + nonmetal)

1. SF_6 ________________________
2. IBr ________________________
3. ________________________________ Carbon monoxide
4. __________________________ Dinitrogen pentoxide

2. Name the following: (Hint: First identify if the compound is ionic or covalent)

a. NaF

b. PbS

c. TiO_2

d. Cr_2O_3

e. Zn_3P_2

f. MnO_2

g. PI_3

h. S_2Br_2

i. IBr_5

j. XeF_4

3. Write formulas for the following compounds: (See hint above!)

a. Barium iodide

b. Palladium(II) bromide

c. Zinc arsenide

d. Gold(III) oxide

e. Lead(IV) oxide

f. Copper(I) sulfide

g. Sulfur hexafluoride

h. Nitrogen trichloride

i. Chlorine dioxide

Nomenclature Lab: Polyatomic Anions and Acids

4. Write the names for the following compounds. If the compound is an **acid**, name as an acid and not an ionic compound to receive full credit.

a. Na_2SO_4

b. $Ca(ClO)_2$

c. $Ba(NO_3)_2$

d. $Al(OH)_3$

e. $Fe(NO_2)_3$

f. $CuSO_3$

g. Cu_2CO_3

h. NH_4ClO

i. $Ni_3(PO_4)_2$

j. $Pb(OH)_2$

l. $HBrO_3$

m. $HBrO_2$

n. $HBrO$

o. HBr

p. $HBrO_4$

q. H_2SO_4

r. HNO_3

s. H_3PO_3

5. Write the chemical formulas for the following compounds.

a. sodium phosphate

b. iron(II) sulfate

c. calcium bromate

d. aluminum nitrate

e. zinc sulfite

f. copper(I) chlorite

g. ammonium hydroxide

h. silver nitrite

i. lead(II) phosphate

j. potassium bicarbonate

k. iodic acid

l. hypoiodous acid

m. periodic acid

n. iodous acid

o. hydroiodic acid

p. sulfurous acid

q. nitric acid

r. nitrous acid

s. phosphoric acid

t. acetic acid

u. carbonic acid

CH 151 Summer 2025:
"Density" ***Lab*** **-** *Instructions*

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-4-3 through I-4-8 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/t/4.htm**

The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.

Step Three:

Bring the printed copy of the lab with you on Tuesday, July 1. During lab, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in (**pages I-4-5 through I-4-8 *only* to avoid a point penalty**) at 8 AM on Monday, July 7.** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor. Good luck on this assignment!

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Density

Density, like color, odor, melting point, and boiling point, is a physical property of matter. Therefore, density may be used in identifying matter. Density is defined as mass per unit volume and is expressed mathematically as $d = m/V$ (d is density, m is mass, and V is volume).

The system of measurement used universally by scientists is the metric system. In the metric system, the unit of mass is the gram (g), the unit of volume for a liquid is milliliters (mL), and the unit of volume for a solid is a cubic centimeter (cm^3). Therefore, the density of a liquid is usually expressed as grams per milliliter (g/mL), and the density of a solid is expressed as grams per cubic centimeter (g/cm^3). **[Note: 1 mL = 1 cm^3]**

When we say that gold (density = 19.7 g/cm^3) is more dense than aluminum (2.70 g/cm^3), we mean that a gold cube is heavier (has a larger mass) than an aluminum cube of the same size. For example, a block of gold that is 1 cm^3 would have a mass of 19.7 grams while the same size block of aluminum would have a mass of only 2.70 grams.

Determination of density of certain physiological liquids is often an important screening tool in medical diagnosis. For example, if the density of urine differs from normal values, this may indicate a problem with the kidneys secreting substances that should not be lost from the body. The determination of density is almost always performed as part of an urinalysis. Another example utilizing density is the determination of total body fat. Muscle is more dense than fat; therefore, by determining total body mass and volume, the muscle-to-fat ratio can be calculated.

In this experiment you will determine densities of various substances by measuring their mass with a balance and their volume with graduated cylinders. You will further determine the percent concentration of salt dissolved in water in an unknown solution graphically based on experimentally determined densities of known salt solutions.

PROCEDURE:

Part A: Determining the Density of Water

1. Record the mass of a clean and dry 10.00 mL graduated cylinder to 0.001g.
2. Fill this 10 mL graduated cylinder approximately halfway with distilled water. Record the mass of your graduated cylinder *with this volume of water in it.*
3. Calculate the mass of the water. Remember to show math setups on data sheet.
4. Read the volume of water using the bottom of the meniscus as demonstrated by your instructor. Record your volume to the hundredth decimal place value (i.e. 4.23 mL). [Remember that sig figs are the number of units known plus one estimated value]
5. Calculate the density of the water. (Remember: density = mass/volume)

Procedure continued on next page

Part B: Determining the Density of a Solution.

NOTE: The concentration of a solution is sometimes described in terms of the solution's percentage composition on a weight basis. For example, a 5% salt (NaCl) solution contains 5 g of NaCl per 100 g of solution, which corresponds to 5 g of salt per 95 g of water.

1. Clean and dry the <u>same</u> 10 mL graduated cylinder. Fill the graduated cylinder halfway with the 5% NaCl solution. Record the mass of the graduated cylinder and salt solution.
2. Calculate the mass of the salt solution. (You determined the mass of the empty graduated cylinder in part A.) (Dispose of the solution in the sink; do not return to reagent bottle!)
3. Record the volume of the solution.
4. Calculate the density of the 5% NaCl solution.
5. Repeat steps 1-4 for the 10%, 15%, and 20% NaCl solutions.
6. Obtain an unknown solution. Record its letter. Repeat steps 1-4 for the unknown solution.

Graphing:

1. Construct a graph *using pencil.* Title the graph and label the y-axis as density (g/mL). Label the x-axis as weight percent composition (%).
2. Spread the axes out so that the data covers as much of the graph as possible. You will need to decide on the size of divisions to mark your graph. Make sure that all divisions are equal. Recall that you will have five known data points from part A and part B (0% (water only), 5%, 10%, 15%, 20%). To determine your divisions of your density (y-axis) you do not need to begin at zero. *Check with your instructor before continuing*.
3. Plot your five known solutions. *Do not plot your unknown on the graph yet!*
4. Using a ruler, draw a best fit line on your graph. *Do not connect the dots!* A best fit line does not intersect all data points. It does not always go through the origin. If your data are scattered, estimate where to draw your best straight line. Roughly an equal number of points should be above the line as below the line. This approximates a mathematical technique called linear regression which judges where to draw the line to minimize the distance from each point to the line.
5. To determine your unknown % concentration, use a ruler and draw a dotted line from the calculated density of your unknown on the y-axis until its intersection with the best fit line. Mark this intersection. Next draw a dotted line from this intersection to the x-axis to determine the % weight concentration at this point on your graph. Your unknown is not necessarily the same % as one of the known solutions.

Part C: Determining the Density of a Solid.

1. Obtain a solid and record its identity.
2. Pour about 30 mL (it does not have to be exact) of distilled water into a <u>clean</u> and <u>dry</u> 50.0 mL graduated cylinder. Record the volume of water to the tenth place value (ie. 31.2 mL) by reading the bottom of the meniscus.
3. Record the mass of the graduated cylinder *and* water.
4. Carefully add the solid to the cylinder so that no water is lost. Add enough solid so that between 10-20 mL of water is displaced. Record the new volume.
5. Record the mass of the graduated cylinder, water *and* solid.
6. Calculate the mass of the solid from the above data.
7. Calculate the volume of the solid from the above data.
8. Calculate the density of the solid.
9. Determine the actual density of your solid in the <u>Handbook of Chemistry and Physics</u> or using Google.
10. Determine your percent error: |(Actual – Experimental)| / Actual x 100%

Determining the Density of Liquids & Solids

Name:

Lab Partner(s):

Part A: Density of Water **(Show calculation set up of *steps)**

1. Mass of graduated cylinder _______________
2. Mass of cylinder and water _______________
3. *Mass of water _______________
4. Volume of water _______________
5. *Density of water _______________

Part B: Density of Solution:

	5% NaCl	10% NaCl	15% NaCl	20% NaCl	Unknown
1.Mass solution & cylinder					
2. Mass of solution					
3. Volume of solution					
4. Density of solution					

6. Unknown # ________ % NaCl in Unknown _________ (determined graphically; attach graph)

Part C: Density of Solid **(show calculation set up for *steps)**

1. Solid Identity _______________
2. Volume of water _______________
3. Mass cylinder & water _______________
4. Volume of water & solid _______________
5. Mass cylinder, water and solid _______________
6. *Mass of solid _______________
7. *Volume of solid _______________
8. *Experimental density of solid _______________
9. Actual density of solid _______________
   (from the Handbook of Chemistry & Physics or using an internet search.)
10. *Percent Error _______________

CONCLUSION: (In complete sentences, summarize the final results for parts B & C: include the unknown number, calculated density, percent error; sources of error, etc.)

POSTLAB QUESTIONS:

1. Compare a 50 mL beaker and a 50 mL graduated cylinder. Which is more precise? Why?

2. In the original Indiana Jones movie, our hero is attempting to claim a precious ancient gold relic from a poor third world country. He estimates the size of his prize and carefully adjusts the <u>volume</u> of sand in his bag to equal that of the gold relic. With the great dexterity that only Indiana Jones possesses, he swiftly but delicately swaps the sand for the gold. After a moment of delight, he realizes he has misjudged and the ancient tomb is not fooled. Why?

3. While panning for gold, you find a nugget that looks like gold. You find its mass to be 1.25g. You know that the density of pure gold is about 20.0 g/cm^3 and that the density of iron pyrite (fool's gold) is 5.0 g/cm^3. Determine if a cubic nugget about 0.40 cm on each side is fool's gold or pure gold. (Show all work)

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CH 151 Summer 2025:

“Chemical Equations & Reaction Types” ***Lab - Instructions***

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-5-3 through I-5-8 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/t/5.htm**

The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.

Step Three:

Bring the printed copy of the lab with you on Tuesday, July 8. During lab, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in (**pages I-5-5 through I-5-8 *only* to avoid a point penalty**) at 8 AM on Wednesday, July 9.** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor. Good luck on this assignment!

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Chemical Equations & Reaction Types Lab

The purpose of this laboratory exercise is to develop skills in writing and balancing chemical equations. The relevance of this exercise is illustrated by a series of demonstration reactions, performed by your lab instructor, which will provide a model to enable the student to predict the products and write balanced chemical equations for a series of similar reactions.

In order to write a balanced chemical reaction, two skills must be mastered.
1) Describe the chemical process: write correct chemical formulas for reactants, predict products and write correct chemical formulas for the products of the chemical reaction.
2) Balance the chemical equation.

A chemical equation is a shorthand way of expressing a chemical change in terms of symbols and formulas. An equation for a reaction cannot be written unless the substances that are reacting and being formed are both known. For an equation to be considered correct, it must be balanced. That is, the number of atoms of each element on the left side of the equation must equal the number of atoms of the same element on the right side. This is an application of the Law of Conservation of Mass. Equations may be written in two general ways: as molecular equations and as ionic equations. We shall only consider molecular equations in this exercise.

There are several conventions which are used in writing chemical equations:
1) The reactants are placed on the left side of the equation and the products on the right side with a single arrow separating the reactants from the products.
2) A plus sign (+) separates each reactant or each product.
3) The physical state of the chemical is often listed as a subscript. (i.e. $H_2O_{(l)}$ and $NaCl_{(s)}$)
4) A symbol may be placed above the arrow to indicate conditions needed for the reaction to occur; for example: Δ indicates that heat must be applied.

<u>Guidelines for balancing chemical equations</u>

The chemical equations we will encounter in this exercise are balanced "by inspection". The following guidelines are just helpful suggestions to facilitate the balancing process.
1) Determine the type of reaction (i.e. combination, decomposition, replacement, etc.)
2) Write the correct formula for reactants. Once the correct formula is written it must not be changed during the subsequent balancing operation.

*Note: The seven diatomic elements, when uncombined, are written with subscripts of 2 (H_2; O_2; etc.)

3) Determine the products and write the correct formula for each product. Once the correct formula is written it must not be changed during the subsequent balancing operation.
4) Balance the chemical equation. Do NOT change any chemical formulas while balancing.
    a) Choose the compound with the greatest number of atoms (excluding H and O) and balance the number of atoms of that element on both sides of the equation. This is done by placing the appropriate coefficient in <u>front</u> of the formula of the element or compound on the other side of the arrow that contains that same element. The coefficient is chosen so that when the coefficient is multiplied by the subscript for that element, the number of atoms of that element is equal to the number of atoms of the same element on the other side of the arrow.
    b) Continue until the number of atoms of each element is the same on both sides of the arrow.
    c) Check all coefficients to see that they are whole numbers and the lowest possible ratio.

The following example illustrates these guidelines.

$Ca(OH)_2 + H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O$

Start by balancing the calcium atoms in calcium phosphate first, since calcium phosphate contains the most atoms of an element other than H or O. This requires a coefficient of 3 to be placed in front of $Ca(OH)_2$ on the other side of the arrow.

$3\ Ca(OH)_2 + H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O$

Next balance the phosphate (if a polyatomic is found on both sides of the equation, it is easier to balance for the polyatomic than as each type of element) by putting a 2 in front of H_3PO_4.

$3\ Ca(OH)_2 + 2\ H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O$

The hydrogen atoms now total 12 on the left side, 6 from the 3 $Ca(OH)_2$ "molecules" and 6 from 2 H_3PO_4 molecules. Therefore, place a 6 in front of the formula for water and the equation will be balanced.

$3\ Ca(OH)_2 + 2\ H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6\ H_2O$

All coefficients should be **whole numbers** and the **lowest possible ratio**.

Categories of Chemical Reactions:

Most chemical reactions can be grouped into one of four categories:

1) **Combination reactions** $A + B \rightarrow X$

2) **Decomposition reactions** $X \rightarrow A + B$

3) **Single replacement reactions** $A + BX \rightarrow AX + B$
(Metal replace metals; non-metals replace non-metals.)

4) **Double displacement reactions** $AX + BY \rightarrow AY + BX$
 a) Precipitation (solid forms)
 b) Acid/Base (water is formed) [sometimes called neutralization]

Knowledge of the kind of reaction is useful in predicting the products in a particular reaction. Your instructor will demonstrate several reactions of each category, predicting the products, writing and balancing the chemical equation in each case. Using these as models, you will write and balance chemical equations of similar reactions.

Chemical Equations

Name:

Write balanced chemical equations for each reaction below. *Remember the seven diatomics!*

A. COMBINATION: A + B → X

1) Magnesium metal burning in air.

2) The reaction of iron with oxygen to yield iron(III) oxide.

3) The reaction of sodium metal with chlorine gas.

4) The reaction of calcium with fluorine gas.

5) The reaction of ammonia (NH_3) with hydrogen monochloride to yield ammonium chloride.

B. DECOMPOSITION: X → A + B

1) The decomposition of ammonium dichromate, $(NH_4)_2Cr_2O_7$, into nitrogen, water, and chromium(III) oxide.

2) The decomposition of nitrogen triiodide into its elements.

3) The decomposition of potassium chlorate to potassium chloride and oxygen.

4) The thermal decomposition of ammonium carbonate into ammonia, carbon dioxide and water

5) The decomposition of lead(IV) oxide into its elements.

C. SINGLE REPLACEMENT: AX + B → BX + A

1) The reaction of a solution of silver nitrate with copper metal (copper(II) nitrate is a product).

2) The reaction of sodium metal with water to create hydrogen gas and sodium hydroxide.

3) Zinc metal with sulfuric acid (zinc sulfate is a product).

4) Chlorine with aqueous sodium bromide.

5) Aluminum metal with aqueous copper(II) sulfate.

D. DOUBLE DISPLACEMENT: $AX + BY \rightarrow AY + BX$

1) The reaction of aqueous solution of calcium chloride with ammonium carbonate.

2) The action of vinegar (dilute acetic acid) on sodium bicarbonate.

3) The reaction of dihydrogen monosulfide on a solution of lead(II) nitrate.

4) The reaction of solutions of sodium chloride with silver nitrate.

5) The reaction of magnesium chloride with sulfuric acid.

POSTLAB QUESTIONS: Write balanced equations and classify the type of reaction.

1. Calcium reacts with chlorine

2. Sodium chloride is mixed with lead(II) nitrate

3. Sodium reacts with zinc sulfate

4. Diphosphorus pentoxide breaks down into its elements.

5. Metallic aluminum reacts with nickel(II) nitrate

CH 151 Summer 2025:
"Chemical Models"
Lab - Instructions

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-6-3 through I-6-6 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/t/6.htm**

The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.

Step Three:

Bring the printed copy of the lab with you on Wednesday, July 9. During lab, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in** (pages I-6-5 through I-6-6 *only* to avoid a point penalty) **at 8 AM on Monday, July 14.** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor. Good luck on this assignment!

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Chemical Models Lab

A chemical bond is a force that holds groups of two or more atoms together and makes them function as a unit. Bonding involves only the valence (outer shell) electrons of atoms. In an **ionic bond**, valence electrons are transferred from a metal to a nonmetal. In a **covalent bond**, valence electrons are shared between atoms forming molecules. In this lab we will only consider covalent bonds.

The **Lewis structure** is a representation of how valence electrons are arranged among atoms in a molecule. It shows us how chemical bonds are used to hold together the atoms in a molecule. In drawing Lewis structures, we include only valence electrons, which are represented as dots. When a covalent bond forms, two electrons are shared, represented as a line. The rules for drawing Lewis structures are based on the **Octet Rule**, which states that the most important requirement for the formation of a stable compound is that the atoms achieve a noble gas electron configuration, or eight valence electrons.

Rules for drawing Lewis structures:

1. Determine the total number of valence electrons (outer shell electrons) for the compound. This corresponds to the "A" group the atom belongs on the periodic table, not the atomic number. For example, CO_2: carbon is in group IVA and has 4 valence electrons, oxygen is in group VIA and each has 6 valence electrons, giving a total of 16 valence electrons for the molecule.

2. Determine the central atom (the atom that is least electronegative).
   a. carbon or silicon are <u>always</u> in the middle.
   b. hydrogen is <u>never</u> in the middle.
   c. oxygen is usually not in the middle
   d. the halogens (F, Cl, Br, I) are usually not in the middle.

3. Draw the basic structure: the central atom connected to each of the surrounding atoms by a <u>single bond</u>. A single bond is a shared electron pair.

4. The octet rule for the outer atoms: Surround each outer atom with eight electron dots (four pairs of electrons). *Remember, the covalent bond counts as 2 electrons for each atom to which it is attached.
   *Remember, hydrogen can only have two valence electrons (no lone electrons for H)

5. The octet rule for the center atom:
   *Count the number of electrons; each line (covalent bond) counts as 2, each dot as 1.
   a) If there are any extra electrons from step 1, put these on the central atom.
   b) Does the center atom have an octet?
      i) Yes☺, this is your Lewis structure
      ii) No☹, you must make double or triple bonds. A double bond represents 4 shared electrons. When you draw a double bond, you must erase two electrons from the outer atom attached to the double bond and move it into the double bond. When you draw a triple bond, you must move 4 electrons from the outer atom.

**Hydrogen cannot make a double bond. Halogens do not make double bonds.*

Electron Pair Geometry and Bond Angle

Two systems are used to describe the three-dimensional geometry of molecules. The number of electron pairs surrounding the central atom determines its **electron pair geometry** (**EPG**) and **molecular geometry** (**MG**). All electrons, both shared and unshared, have a negative charge. Since like charges repel, electron pairs try to keep as far from each other as possible.

We will refer to electron pairs, both shared and unshared, as **electron clouds**. Each unshared pair of electrons surrounding the central atom occupies an electron cloud. In addition, each atom attached to the central atom (either by a single, double or triple bond) occupies an electron cloud.

In the EPG model, all electron clouds are positioned as far apart as possible to minimize electrostatic repulsion between negative charges. When there are two electron clouds surrounding the central atom, the furthest distance apart they can get is 180° from each other that leads to a **linear** arrangement in space. When there are three electron clouds, the furthest distance apart is 120° from each other, in a **triangular planar** arrangement in space. When there are four electron clouds, the furthest distance apart is about 109° that leads to a **tetrahedral** arrangement of electron clouds.

Molecular Geometry

The molecular geometry describes the three dimensional **arrangement of atoms** around the central atom. We have just seen that based on the number of electron clouds surrounding the central atom we can determine the EPG geometry and bond angle. By further dividing the electron clouds (into the number of clouds that are unshared pairs and those that surround atoms) we can determine the molecular geometry (MG) of the compound. In determining EPG geometry, all electron clouds are considered. To determine the molecular geometry based on the EPG geometry, we consider only electron clouds that surround atoms.

Below is a chart summarizing electron geometry and molecular shape. Notice that if there are zero non-bonding/unshared electron pairs, the EPG geometry and molecular geometry are the same.

e- clouds (total)	Atom clouds	LonePair Clouds	Electron Pair Geometry (EPG)	Bond Angle	Molecular Geometry (MG)
2	2	0	Linear	180°	Linear
3	3	0	Trigonal Planar	120°	Trigonal Planar
3	2	1	Trigonal Planar	120°	Bent
4	4	0	Tetrahedral	109°	Tetrahedral
4	3	1	Tetrahedral	109°	Trigonal Pyramid
4	2	2	Tetrahedral	109°	Bent

Polarity: Molecules that have an imbalance or asymmetrical distribution of electrical charge are said to be **polar**. This imbalance of electrical charge is due to a combination of bond polarities (differences in electronegativities of the bonded atoms) and the shape of the molecule. If all bonds in the molecule are the same (i.e. the molecule is symmetrical), the molecule is **nonpolar (NP)**. For example, CCl_4 has polar C-Cl bonds, but is a non-polar molecule because the shape results in all the negative areas canceling each other. Thus, the molecule does not have a negative and positive end so it is a nonpolar molecule.

Chemical Bonding and Molecular Models

Name:
Lab Partner(s):

Procedure: Draw the Lewis structure and describe the Lewis structure for the following molecules. Complete the table below. *The table of EPG and MG terms on the previous page will be helpful while completing this worksheet.*

Part A: Overview of shapes

Molecule	# Val e$^-$	Draw the Lewis Structure	Electron Pair Geometry / Molecular Geometry	Bond Angle	Polar *or* NP
CH_4			*EPG:* *MG:*		
NF_3			*EPG:* *MG:*		
H_2O			*EPG:* *MG:*		
CO_2			*EPG:* *MG:*		
SO_3			*EPG:* *MG:*		
SO_2			*EPG:* *MG:*		

Part B: More Lewis Structures with one central atom

Molecule	# Val e$^-$	Draw the Lewis Structure	Electron Pair Geometry / Molecular Geometry	Bond Angle	Polar *or* NP
$TeCl_2$			*EPG:* *MG:*		
CF_2Cl_2			*EPG:* *MG:*		
SeO_2			*EPG:* *MG:*		
HCN			*EPG:* *MG:*		
PH_3			*EPG:* *MG:*		
CH_2O			*EPG:* *MG:*		
N_2O *N in middle*			*EPG:* *MG:*		
NO_2^{-1}			*EPG:* *MG:*		
CO_3^{2-}			*EPG:* *MG:*		

CH 151 Summer 2025:

“Percent Potassium Chlorate” ***Lab*** **-** *Instructions*

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-7-3 through I-7-6 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/t/7.htm**

The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.

Step Three:

Bring the printed copy of the lab with you on Monday, July 14. During lab, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in** (pages I-7-5 through I-7-6 *only* to avoid a point penalty) **at 8 AM on Tuesday, July 15.** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor. Good luck on this assignment!

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Percent Potassium Chlorate Lab

Once we are able to describe pure substances in terms of atoms and molecules, and in terms of compounds and elements, we can begin to understand chemical reactions in a quantitative manner. We can predict product amounts and develop economical ways to produce the many synthetic substances we need. Furthermore, we have the ability to analyze substances based upon the amount of products formed in a reaction. This experiment is an illustration of just such a technique.

Potassium chlorate ($KClO_3$) decomposes on heating to produce potassium chloride and oxygen according to the equation below:

$$\mathbf{2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)}$$

Since the decomposition of 2 moles of $KClO_3$ releases 3 moles of oxygen, you can determine the amount of $KClO_3$ in a sample from the <u>weight loss due to loss of oxygen</u>. In this experiment, you will determine the percent $KClO_3$ in an unknown mixture containing an unreactive chloride. By converting the weight loss to moles of oxygen lost, we calculate the moles of potassium chlorate in the starting material. From the moles of potassium chlorate we can convert to mass and then the percent of potassium chlorate in the unknown mixture.

A catalyst, MnO_2 (manganese (IV) oxide), is added to the reaction mix to speed up the reaction. Like all catalysts, the same amount of catalyst is present at the end of the reaction as in the beginning. Therefore, we will include the mass of the catalyst in with the mass of the test tube.

In a thermal decomposition such as this, the product must be heated to a constant weight before you can be sure the decomposition is complete. After the first heating, cooling and weighing, the sample must be heated again, cooled and reweighed. This process is continued until two successive weightings are within 5 mg (0.005 g) of each other (three or four heatings.)

PROCEDURE: - *You must wear safety goggles while performing this lab!*
Also, while waiting for the mixture to heat or cool, consider working on the postlab questions.

1. Set up a ring stand with a triangle as demonstrated by your teacher. The small white crucible should fit inside the triangle.

2. Place about 0.5 g of manganese(IV) oxide into a clean, dry small white crucible. Heat the crucible and catalyst with a Bunsen burner for about 3 minutes to drive off any moisture that may be in the catalyst or crucible.

3. When the crucible is cool enough to touch, record the entire mass to the nearest 0.001g.

4. Add between 2.0 to 2.5 grams of the unknown mixture to the crucible. Mix the contents to obtain a somewhat uniform mixture. Record the mass of the crucible plus catalyst plus mixture to the nearest 0.001 g. Be sure to also record your unknown number!

5. Begin heating the crucible gently at first followed by a more aggressive treatment for a total of 10 minutes. Be aware that the sample may begin to bubble and spurt; if this happens, turn the flame down a bit.

6. Allow the sample to cool to room temperature. Record the mass to the nearest 0.001 g.

7. Reheat your sample for 5 minutes. Cool and record the mass. If your mass is within 0.005 g of the mass after the first heating, congratulations, you can move on to calculations. If not, you must reheat, cool, and weigh until you have two successive masses within 0.005 g of each other.

8. Clean up! Complete postlab questions.

CALCULATIONS: *Remember to show relevant calculations on your lab sheet*

1. Write a balanced equation for the decomposition of potassium chlorate.
2. Determine the **mass of oxygen lost** (**α**, below in the equation).
3. Use the balanced equation to determine the mass of potassium chlorate decomposed (**λ**, below, in the equation.) You will also need to calculate the **molar mass of O_2** (**β,** below) and the **molar mass of $KClO_3$** (**δ**, below).
4. Determine the percentage of potassium chlorate in the original white mixture.

The following equation might prove useful for this lab:

$$\lambda \text{ g } KClO_3 = (\alpha \text{ g } O_2 \text{ lost}) * \left(\frac{\text{mol } O_2}{\beta \text{ g } O_2}\right) * \left(\frac{2 \text{ mol } KClO_3}{3 \text{ mol } O_2}\right) * \left(\frac{\delta \text{ g } KClO_3}{1 \text{ mol } KClO_3}\right)$$

PERCENT POTASSIUM CHLORATE

Name:
Lab Partner(s):

DATA:

Unknown Number __________

1. Mass of crucible + catalyst
   (after drying moisture & before adding unknown __________

2. Mass of crucible + catalyst + unknown
   (before heating) __________

3. Mass after first heating ___________

4. Mass after second heating __________

   Mass after third heating (if necessary) __________

   Mass after fourth heating (if necessary) __________

CALCULATIONS: (Show set up for each calculation)

7. Mass of oxygen lost ___________

8. Mass of potassium
   chlorate decomposed _____________

9. Mass of unknown _____________

10. % $KClO_3$ in unknown mixture ____________

CONCLUSION: (Unknown # and calculated %$KClO_3$; possible sources of error)

POSTLAB QUESTIONS:

1. Calculate the % oxygen by mass for the following (show calculations). Use at least four significant figures.

a) lithium nitrate

b) sodium hydrogen carbonate

2. Would the calculated % $KClO_3$ in the unknown be higher or lower if all the moisture was not removed from the catalyst in the first heating, before adding the unknown mixture? Explain your prediction.

3. A white powder is a mixture of potassium chlorate and potassium chloride. Upon heating, the potassium chlorate decomposes into potassium chloride and oxygen. If you start with 2.220 g of the mixture and after heating are left with 1.700 g of potassium chloride, calculate the weight percent of potassium chlorate in the original mixture.

CH 151 Summer 2025:

Problem Set #1

Instructions

Step One:

- **Learn the material** for Problem Set #1 by **reading Chapter 1** of the textbook and/or by watching the videos found on the website (https://mhchem.org/151)
- **Try the problems** for Problem Set #1 found on the next pages on your own first. **Write out the answers (and show your work) by hand (on a tablet or paper)**; do not type your answers (and work) to avoid a point penalty. If you write the answers on the problem set itself, you will receive fewer points. Include your name on your problem set!
- If you get stuck on a particular problem, you can watch the recitation video for Problem Set #1, found using this link: **http://mhchem.org/t/n.htm**

Step Two:

We will go over Problem Set #1 during recitation. ***Self correct all problems*** of your problem set before turning it in at the end of recitation.

Problem Set #1 will be **due on Wednesday, June 25 at 8 AM**.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

CH 151 Problem Set #1 - *Chapter 1*

* **Complete problem set on separate pieces of paper** showing all work, circling final answers, etc.

* Self correct problem set during recitation (**June 25, 8 AM**) before turning in to the instructor

Important Tables and/or Constants: 1 cm^3 = 1 mL; k = 10^3; c = 10^{-2}; m = 10^{-3}; $\mu = 10^{-6}$; n = 10^{-9}; **273.15**, periodic table (http://mhchem.org/pertab)

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1. Determine the number of significant figures in each of the following measured values:
   a. 0.1111010
   b. 0.0000007
   c. 4000
   d. 4000.
   e. 0.0040
   f. 67,000,100
2. Round off each of the following numbers to the number of significant figures indicated in parentheses.
   a. 3883 (two)
   b. 0.00003011 (two)
   c. 4.4050 (three)
   d. 2.1000 (three)
3. Carry out the following mathematical operations, expressing your answers to the correct number of significant figures. Assume that all numbers are measured quantities.
   a. 3.33 x 3.03 x 0.0333
   b. 300,003 x 20,000 x 1.33333
   c. (2.322 + 4.00) / (3.200 + 6.73)
   d. 7.403 / (3.220 x 5.000)
   e. (5600 x 300) / (22 x 97.1)
4. Carry out the following mathematical operations, expressing your answers to the correct number of significant figures. Assume that all numbers are measured quantities.
   a. 237 + 37 + 7
   b. 3.111 + 3.11 + 3.1
   c. 235.45 + 37 + 36.4
   d. 4.72 - 3.908
   e. 46,230 + 325 + 45
5. Express the following numbers in scientific notation.
   a. 787.6
   b. 0.01798
   c. 40.0
   d. 675,000
6. Identify the metric prefixes corresponding to each of the following powers of ten, or vice versa.
   a. 10^{-3} b. 10^{-9} c. 10^3 d. micro e. centi

Problem Set #1 continues on the next page

7. Calculate the volume of each of the following objects, each of which has a regular geometrical shape.
   a. a cube of steel whose edge is 3.5175 mm ($V = s^3$)
   b. a spherical marble with a radius of 1.212 cm ($V = {}^4/_3\pi r^3$)
   c. a bar of iron 6.0 m long, 0.10 m wide and 0.20 m high ($V = l * w * h$)
   d. a cylindrical rod of copper with radius = 3.2 mm and length = 62 mm ($V = \pi r^2 L$)
8. A piece of metal weighing 187.6 g is placed in a graduated cylinder containing 225.2 mL of water. The combined volume of solid and liquid is 250.3 mL. What is the volume (in cm^3) and density (in grams per milliliter) of the metal?
9. A pediatric dosage of a certain analgesic is 225 mg/kg of body weight per day. How much analgesic, in milligrams per day, should be administered to a child who weighs 12.3 kg?
10. A 2004 US penny (zinc plated with a thin layer of copper) with a mass of 2.552 g contains 2.448 g of zinc. What is the mass percentage in the penny of copper? of zinc?
11. Carry out the following temperature scale conversions. **T(K) = T(°C) + 273.15**
    a. Mercury freezes at 234.3 K. What is this temperature in degrees Celsius?
    b. Normal body temperature for a chickadee is 41.0 °C. What is this temperature in Kelvin?
    c. A recommended temperature setting for household hot water heaters is 60. °C. What is this temperature in degrees Fahrenheit? T(°F) = 1.8*T(°C) + 32
12. What should the recorded uncertainty be (±0.1 unit, ±0.01 unit, etc.) for measurements made using the following measuring device scales?
    a. a graduated cylinder scale with markings in 10 mL intervals
    b. a meter stick scale with markings in 1 cm intervals
    c. a buret (a volumetric device) scale with markings in 0.1 mL intervals
    d. a double pan mass balance scale with markings in 100 g intervals
13. With a high grade measuring device, the length of an object is determined to be 13.452 mm. Three students are asked to determine the length of the same object using a lower grade measuring device. How do you evaluate the following work of the three students with regard to accuracy and precision?

Trial	Student A	Student B	Student C
1	13.6 mm	13.4 mm	13.9 mm
2	13.9 mm	13.5 mm	13.9 mm
3	13.3 mm	13.5 mm	14.0 mm
4	13.6 mm	13.4 mm	14.1 mm

14. The accepted value for the normal boiling point of benzaldehyde, a substance used as an almond flavoring, is 178 °C. In a laboratory setting, three students are asked to experimentally determine the normal boiling point of benzaldehyde. Their results are:

    Student 1: 175 °C *Student 2:* 190. °C *Student 3*: 181 °C

    Calculate the percent error associated with each student's reported boiling point. *Helpful formula:* **% error = absolute value |(difference)| / (accepted) * 100%**

Problem Set #1 continues on the next page

15. The following are properties of the metal beryllium. Classify them as **physical** or **chemical**.
    a. In powdered form, it burns brilliantly on ignition.
    b. Bulk metal melts at 1287 °C
    c. It has a density of 1.85 g/cm^3 at 20 °C.
    d. It is a relatively soft silvery white metal.
16. Consider the following classifications of matter: **heterogeneous mixture**, **homogeneous mixture** and **pure substance**
    a. In which of these classifications must the composition be constant?
    b. In which of these classifications is separation into simpler substances using physical means possible?
17. Based on the information given, classify each of the pure substances A through D as **elements** or **compounds**, or indicate that no such classification is possible because of insufficient information.
    a. Substance A cannot be broken down into simpler substances by chemical means
    b. Substance B cannot be broken down into simpler substances by physical means
    c. Substance C readily dissolves in water
    d. Substance D readily reacts with the element chlorine
18. Indicate whether each of the following statements is **true** or **false**.
    a. Compounds can be separated into their constituent elements using chemical means.
    b. Elements can be separated into their constituent compounds using physical means.
    c. A compound must contain at least two elements.
    d. A compound is a physical mixture of different elements
19. Give the name of the element associated with each of the following chemical symbols, or vice versa.
    a. Li
    b. He
    c. F
    d. Zn
    e. mercury
    f. chlorine
    g. gold
    h. selenium
20. Write the chemical symbol for each member of the following pairs of elements:
    a. copper and cobalt
    b. potassium and phosphorus
    c. iron and iodine
    d. silicon and silver

CH 151 Summer 2025:

Problem Set #2

Instructions

Step One:

- **Learn the material** for Problem Set #2 by **reading Chapter 2 (sections 2.1-2.4) and Chapter 4 (section 4.3)** of the textbook and/or by watching the videos found on the website (https://mhchem.org/151)
- **Try the problems** for Problem Set #2 found on the next pages on your own first. **Write out the answers (and show your work) by hand (on a tablet or paper)**; do not type your answers (and work) to avoid a point penalty. If you write the answers on the problem set itself, you will receive fewer points. Include your name on your problem set!
- If you get stuck on a particular problem, you can watch the recitation video for Problem Set #2, found using this link: **http://mhchem.org/t/b.htm**

Step Two:

We will go over Problem Set #2 during recitation. ***Self correct all problems*** of your problem set before turning it in at the end of recitation.

Problem Set #2 will be **due on Wednesday, July 2 at 8 AM**.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

CH 151 Problem Set #2 - *Chapter 2.1-2.4 and Chapter 4.3*

* **Complete problem set on separate pieces of paper** showing all work, circling final answers, etc.
* Self correct problem set during recitation (**July 2, 8 AM**) before turning in to the instructor

Covering: **Chapter Two (sections 2.1 - 2.4 only)** *and* **Chapter Four (section 4.3 only)**
Important Tables and/or Constants: 1 mol = 6.022×10^{23}, periodic table (http://mhchem.org/pertab)

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1. On the basis of its formula, classify each of the following substances as an element or a compound.
    a. AlN
    b. CO_2
    c. Co
2. Match the terms **proton neutron**, and **electron** to each of the following subatomic particle descriptions. It is possible that more than one term may apply in a given situation.
    a. has no charge
    b. has a charge equal to but opposite in sign to that of an electron
    c. is not found in the nucleus
    d. has a positive charge
3. Indicate whether each of the following statements about the nucleus of an atom is true or false.
    a. The nucleus accounts for almost all the volume of an atom.
    b. The nucleus can be positively or negatively charged, depending on the identity of the atom.
    c. The nucleus of an atom contains an equal number of protons, neutrons and electrons.
    d. The nucleus of an atom is always positively charged.
4. What is the complete symbol (${}^{A}_{Z}X$) for neutral atoms composed of the following sets of subatomic particles?
    a. 4 protons, 4 electrons and 5 neutrons
    b. 7 protons, 7 electrons and 8 neutrons
    c. 15 protons, 15 electrons and 16 neutrons
    d. 20 protons, 20 electrons and 28 neutrons
5. Determine the number of protons, electrons, and neutrons in each of the following neutral atoms.
    a. ${}^{35}_{17}Cl$
    b. ${}^{55}_{25}Mn$
    c. ${}^{127}_{53}I$
    d. ${}^{209}_{83}Bi$
6. Four naturally occurring isotopes of the element strontium exist. Knowing that the lightest isotope has a mass number of 84 and that the other isotopes have, respectively, 2, 4, and 5 more neutrons, write the complete symbol (${}^{A}_{Z}X$) for each of the four isotopes.

Problem Set #2 continues on the next page

Problem Set #2, Continued from previous page

7. Each of the following elements has only two naturally occurring isotopes. Determine, in each case, which isotope is more abundant, using only the atomic mass value for the element that is listed on the periodic table.
    a. ${}^{10}_{5}B$ and ${}^{11}_{5}B$
    b. ${}^{69}_{31}Ga$ and ${}^{71}_{31}Ga$
    c. ${}^{107}_{47}Ag$ and ${}^{109}_{47}Ag$
    d. ${}^{203}_{81}Tl$ and ${}^{205}_{81}Tl$
8. Calculate the atomic mass of copper on the basis of the following percent composition and isotopic mass data for the naturally occurring isotopes: **copper-63** : 69.09% (62.9298 amu) , and **copper-65** : 30.91% (64.9278 amu)
9. Name each of the following fixed-charge binary ionic compounds.
    a. BeS
    b. $GaCl_3$
    c. CaO
10. Name each compound in the following pairs of variable-charge binary ionic compounds.
    a. $SnCl_4$ and $SnCl_2$
    b. FeS and Fe_2S_3
    c. AuI and AgI
11. Write chemical formulas for both ions in each of the following pairs of polyatomic ions.
    a. nitrate and nitrite
    b. chlorate and perchlorate
    c. phosphate and phosphite
12. In which of the following pairs of compounds are polyatomic ions present in both members of the pair?
    a. SO_3 and $CaSO_4$
    b. NH_4Br and KClO
13. Name each compound in the following pairs of polyatomic ion containing compounds.
    a. $CuNO_3$ and $Cu(NO_3)_2$
    b. $Pb_3(PO_4)_2$ and $Pb_3(PO_4)_4$
14. Name the following binary molecular compounds.
    a. S_4N_2
    b. SO_3
15. Write chemical formulas for the following binary molecular compounds.
    a. disulfur monoxide
    b. tetraphosphorus hexoxide
    c. carbon dioxide
16. Name each of the following compounds as acids.
    a. $HClO_4$
    b. $HClO_3$
    c. $HClO_2$
    d. HClO
    e. HCl

Problem Set #2 continues on the next page

17. Calculate the molar mass (to 0.01 g/mol) of each of the following substances.
    a. $NaHCO_3$ (baking soda, or sodium bicarbonate)
    b. Tl_2SO_4 (thallium(I) sulfate, a rat and ant poison)
18. Calculate the percent element composition for each of the following compounds. (Round off all atomic masses to 0.01 g/mol before using them.)
    a. $C_{10}H_8$ (naphthalene, ingredient in some mothballs)
    b. NaCN (sodium cyanide, used to extract gold from ores)
19. Calculate the number of molecules or atoms present in each of the following:
    a. 4.69 moles CO
    b. 3.752 g of Li
20. Calculate the mass, in grams, of 0.981 mole of each of the following compounds.
    a. SO_2
    b. S_4N_4
21. Each of the following is a correctly written molecular formula. In each case write the empirical formula for the substance.
    a. As_4O_6
    b. Pb_3S_4
    c. C_4H_8
22. Given the following percent element composition, determine the empirical formula: **47.26% Cu and 52.74% Cl**
23. Determine the molecular formulas of compounds with the following empirical formulas and molecular masses.
    a. CB_2H_3, 73.3 amu
    b. $C_5H_{10}O_2$, 102 amu
24. Adipic acid, a compound used in the manufacture of nylon, has a molecular mass of 146 g/mol. Its percent composition by mass is 49.30% C, 6.91% H, and 43.79% O. Determine the molecular formula of adipic acid.

CH 151 Summer 2025:

Problem Set #3

Instructions

Step One (all sections):

- **Learn the material** for Problem Set #3 by **reading Chapter 7 (section 7.1)** of the textbook and/or by watching the videos found on the website (https://mhchem.org/151)
- **Try the problems** for Problem Set #3 found on the next pages on your own first. **Write out the answers (and show your work) by hand (on a tablet or paper)**; do not type your answers (and work) to avoid a point penalty. If you write the answers on the problem set itself, you will receive fewer points. Include your name on your problem set!
- If you get stuck on a particular problem, you can watch the recitation video for Problem Set #3, found using this link: **http://mhchem.org/t/c.htm**

Step Two:

We will go over Problem Set #3 during recitation. ***Self correct all problems*** of your problem set before turning it in at the end of recitation.

Problem Set #3 will be **due on Wednesday, July 9 at 8 AM**.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

CH 151 Problem Set #3 - *Chapter 7.1*

* **Complete problem set on separate pieces of paper** showing all work, circling final answers, etc.
* Self correct problem set during recitation (**July 9, 8 AM**) before turning in to the instructor

Covering: **Chapter Seven (section 7.1 only)**
* *Important Tables and/or Constants:* periodic table (http://mhchem.org/pertab)

---

1. What do the symbols in parentheses stand for in the following equations?
    a. $PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s)$
    b. $NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
2. For each of the following balanced equations, indicate how many atoms of each element are present on the reactant and product sides of the chemical equation.
    a. $4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$
    b. $2\ Na + 2\ H_2O \rightarrow 2\ NaOH + H_2$
    c. $2\ Co + 3\ HgCl_2 \rightarrow 2\ CoCl_3 + 3\ Hg$
    d. $H_2SO_4 + 2\ NH_3 \rightarrow (NH_4)_2SO_4$
3. Balance the following chemical equations.
    a. $Fe + O_2 \rightarrow Fe_2O_3$
    b. $NaClO_3 \rightarrow NaCl + O_2$
    c. $Au_2S_3 + H_2 \rightarrow H_2S + Au$
    d. $NH_3 + O_2 \rightarrow N_2O + H_2O$
4. Balance the following combustion equations.
    a. $C_2H_4 + O_2 \rightarrow CO_2 + H_2O$
    b. $C_6H_{12} + O_2 \rightarrow CO_2 + H_2O$
    c. $C_3H_6O + O_2 \rightarrow CO_2 + H_2O$
    d. $C_5H_{10}O_2 + O_2 \rightarrow CO_2 + H_2O$
5. Balance the following chemical equations.
    a. $Al + Sn(NO_3)_2 \rightarrow Al(NO_3)_3 + Sn$
    b. $Na_2CO_3 + Mg(NO_3)_2 \rightarrow MgCO_3 + NaNO_3$
    c. $Al(NO_3)_3 + H_2SO_4 \rightarrow Al_2(SO_4)_3 + HNO_3$
    d. $Ba(C_2H_3O_2)_2 + (NH_4)_3PO_4 \rightarrow Ba_3(PO_4)_2 + NH_4C_2H_3O_2$
6. Classify each of the following chemical reactions as precipitation, decomposition, single-replacement, combustion, acid-base or combination.
    a. $3\ CuSO_4 + 2\ Al \rightarrow Al_2(SO_4)_3 + 3\ Cu$
    b. $K_2CO_3 \rightarrow K_2O + CO_2$
    c. $2\ AgNO_3 + K_2SO_4 \rightarrow Ag_2SO_4(s) + 2\ KNO_3$
    d. $2\ SO_2 + O_2 \rightarrow 2\ SO_3$
    e. $H_2SO_4 + 2\ KOH \rightarrow 2\ H_2O + K_2SO_4$
    f. $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

Problem Set #3 continues on the next page

Problem Set #3, Continued from previous page

7. Identify the products of, and then write a balanced chemical equation for, each of the following chemical reactions.
    a. $AlCl_3 \rightarrow ? + ?$ (decomposition reaction into elements)
    b. $HNO_3 + NaOH \rightarrow ? + ?$ (acid-base reaction)
    c. $Al + Ni(NO_3)_2 \rightarrow ? + ?$ (single replacement reaction)
    d. $Be + N_2 \rightarrow ?$ (combination reaction)
8. Write a balanced chemical equation for the thermal decomposition of each of the following metal carbonates to its metal oxide and carbon dioxide.
    a. $BeCO_3$
    b. Li_2CO_3
    c. $ZnCO_3$
    d. Cs_2CO_3
9. Write a balanced chemical equation for the combustion of each of the following hydrocarbons in air.
    a. C_5H_{12}
    b. C_4H_6
    c. C_7H_8
    d. C_8H_{18}
10. Write a balanced chemical equation for the combustion of each of the following hydrocarbons in air.
    a. C_2H_4O
    b. $C_5H_{10}O$
    c. $C_2H_4O_2$
    d. $C_3H_6O_2$
11. Balance the following chemical equations.
    a. $NH_3 + O_2 + CH_4 \rightarrow HCN + H_2O$
    b. $KClO_3 + HCl \rightarrow KCl + Cl_2 + H_2O$

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CH 151 Summer 2025:

Problem Set #4

Instructions

Step One:

- **Learn the material** for Problem Set #4 by **reading Chapter 4 (sections 4.4 - 4.6 only) and Chapter 3 (sections 3.3 - 3.5 only)** of the textbook and/or by watching the videos found on the website (https://mhchem.org/151)
- **Try the problems** for Problem Set #4 found on the next pages on your own first. **Write out the answers (and show your work) by hand (on a tablet or paper)**; do not type your answers (and work) to avoid a point penalty. If you write the answers on the problem set itself, you will receive fewer points. Include your name on your problem set!
- If you get stuck on a particular problem, you can watch the recitation video for Problem Set #4, found using this link: **http://mhchem.org/t/d.htm**

Step Two:

We will go over Problem Set #4 during recitation. ***Self correct all problems*** of your problem set before turning it in at the end of recitation.

Problem Set #3 will be **due on Tuesday, July 15 at 8 AM**.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

CH 151 Problem Set #4 - *Chapter 4.4-4.6 and Chapter 3.3-3.5*

* **Complete problem set on separate pieces of paper** showing all work, circling final answers, etc.
* Self correct problem set during recitation (**July 15, 8 AM**) before turning in to the instructor

Covering: **Chapter Four (sections 4.4 - 4.6 only) and Chapter 3 (sections 3.3 - 3.5 only)**
Important Tables and/or Constants: periodic table (http://mhchem.org/pertab)

For Problems #1 - #5:

- Calculate the valence electrons in the molecule
- Draw a Lewis structure
- Describe the Electron Pair Geometry and Molecular Geometry for the molecule
- Describe any bond angles in the molecule
- Predict if the molecule is polar or nonpolar

1. Methane, CH_4
2. Nitrogen trichloride, NCl_3
3. Carbon dioxide, CO_2 *(answers on central C)*
4. Acetone, CH_3COCH_3
5. Ammonium ion, NH_4^{1+}

6. For each of the following sets of elements, choose the two that would be expected to have similar chemical properties.
   a. ${}_{11}Na$, ${}_{14}Si$, ${}_{23}V$, ${}_{55}Cs$
   b. ${}_{13}Al$, ${}_{19}K$, ${}_{32}Ge$, ${}_{50}Sn$
   c. ${}_{37}Rb$, ${}_{38}Sr$, ${}_{54}Xe$, ${}_{56}Ba$
   d. ${}_{2}He$, ${}_{6}C$, ${}_{8}O$, ${}_{10}Ne$
7. Give the maximum number of electrons that can occupy each of the following electron ***subshells***.
   a. 6*p* b. 1*s* c. 5*f* d. 4*d*
8. Give the maximum number of electrons that can occupy each of the following electron ***orbitals***.
   a. 1*s* b. 3*d* c. 5*p* d. 4*d*
9. Which of the following electron subshell and electron orbital designations is not allowed?
   a. 2*d* subshell
   b. 4*s* orbital
   c. 3*p* subshell
   d. 2*f* orbital
10. With the help of an Aufbau diagram, write the complete electron configuration for each of the following atoms.
   a. ${}_{6}C$ b. ${}_{10}Ne$ c. ${}_{15}P$ d. ${}_{36}Kr$ e. ${}_{31}Ga$ f. ${}_{48}Cd$

Problem Set #4 continues on the next page

11. Based on total number of electrons present, identify the **neutral element** represented by each of the following electron configurations.
    a. $1s^2\ 2s^2\ 2p^2$
    b. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
    c. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
    d. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$
12. Determine how many unpaired electrons there are in an atom of the following elements. Indicate whether the elements are **paramagnetic** or **diamagnetic**.
    a. lithium
    b. aluminum
    c. calcium
    d. bromine
13. Write the electron configuration for each of the following ions.
    a. S^{2-} b. P^{3-} c. Be^{2+} d. Na^{1+}

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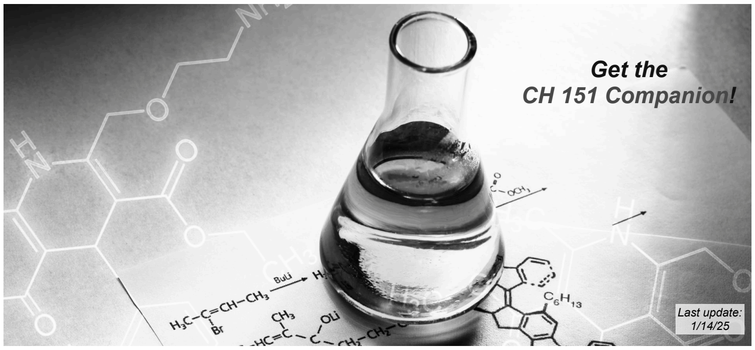
Chemistry 151: Basic Chemistry

Welcome! & Chapter 1



Get the CH 151 Companion!

Last update: 1/14/25

Welcome to Chemistry 151!

Chemistry 151 is the gateway to a successful experience in the "majors level" chemistry classes (Chemistry 221, Chemistry 222 and Chemistry 223 at Mt. Hood Community College)

CH 151 offers students the chance to acquaint themselves with chemistry, math and more before tackling the higher level (and faster paced) classes.

The *goals* of CH 151: learn chemistry, understand sig figs and dimensional analysis, explore math skills needed for chemistry, and have fun! :)

MAR

What is Chemistry?

- "Keme" (earth)
- "Kehmeia" (transmutation)
- "Al-Khemia" (Arabic)
- "alchemy" (Europe's Dark Age)
- "chymistry" (Boyle's 1661 publication)
- "chemistry" (modern)

Khemeia - ancient Egyptian processes for embalming the dead, later extended to metallurgy

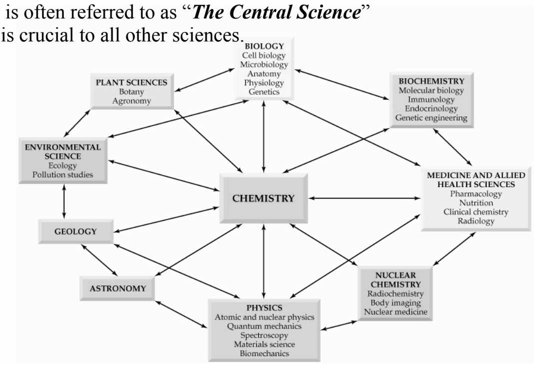
Chemistry is the study of matter and energy

Khemeia (and later chemistry) seen as "occult" by laymen, extended to modern age

MAR

Chemistry: The Central Science

Chemistry is often referred to as "***The Central Science***" because it is crucial to all other sciences.



MAR

The Branches of Chemistry

- **Organic - carbon, nitrogen, oxygen**
- **Inorganic - metals, everything "non-carbon"**
- **Analytical - Spectroscopy, "how much", "what kind"**
- **Physical - measurement, where physics meets chemistry**
- **Biochemical - the chemistry of life**
- **also: geochemistry, astrochemistry, radiochemistry, medicinal chemistry, etc.**

MAR

Metric System

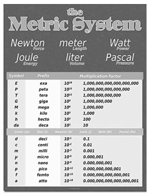
Scientists use the metric system to record measurements (length, mass, volume, temperature, etc.) The metric system uses prefixes which correspond to a power of ten:

COMMON METRIC PREFIXES

PREFIX	ABBREV.	MEANING	NUMERICAL VALUE	
mega-	M	one million	1,000,000	(10^{6})
kilo-	k	one thousand	1,000	(10^{3})
deci-	d	one tenth	0.1	(10^{-1})
centi-	c	one hundredth	0.01	(10^{-2})
milli-	m	one thousandth	0.001	(10^{-3})
micro-	µ	one millionth	0.000001	(10^{-6})
nano-	n	one billionth	0.000000001	(10^{-9})

MAR

Metric System



The same prefixes are used with different types of measurements.

Length **(meter, m)**	**Mass** **(gram, g)**	**Volume** **(liter, L)**	**Time** **(second, s)**
megameter	megagram	megaliter	megasecond
kilometer	kilogram	kiloliter	kilosecond
decimeter	decigram	deciliter	decisecond
centimeter	centigram	centiliter	centisecond
millimeter	milligram	milliliter	millisecond
micrometer	microgram	microliter	microsecond
nanometer	nanogram	nanoliter	nanosecond

MAR

...and many more!

Metric System

Relationships can be obtained from prefix meanings; just replace the prefix with its numerical equivalent

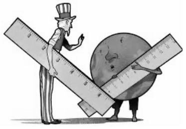
1 **kilo**meter = **1000** meters *(kilo = 10^3 or 1000)*
1 **deci**meter = **0.1** meters *(deci = 10^{-1} or 0.1)*
1 **centi**meter = **0.01** meters (*centi = 10^{-2} or 0.01 - note that this is equivalent to saying* **100 cm = 1 meter**)

MA

Metric System

Common "Bridges" Between English and Metric Systems

QUANTITY	BRIDGE
Length	2.54 cm = 1.00 in
	1.61 km = 1.00 mile
Mass	454 g = 1.00 lb
Volume	1.00 L = 1.06 qts



Try to use the metric system at all times!

MAR

Physical Quantities

Measurable physical properties such as height, volume, and temperature are called ***Physical quantity***. A number and a unit of defined size is required to describe physical quantity.

MAR

Physical Quantities

A number alone doesn't say much!

Say an average textbook weighs 1.

The question would then be asked 1 what? 1 pound? 1 kilogram? 1 ounce?

You have to mention the unit of mass *along with the number* for the statement to be meaningful.

MAR

Physical Quantities

Physical quantities measured using many different units. Mass can be measured in pounds, kilograms, ounces, etc.

To avoid confusion, scientists around the world have agreed to use a set of standard units known as the ***International System of Units*** or ***SI units*** for some common physical quantities.

MAR

SI Units

In **SI Units**,

- mass measured in kilograms (kg)
- length measured in meters (m)
- volume measured in cubic meters (m^3)
- time measured in seconds (s).

Many other units derived from SI units.

- speed measured in meters per second (m/s)
- density measured in grams per cubic centimeter (g/cm^3).

MAR

Measuring Mass

Mass is a measure of amount of matter in an object.

Weight is a measure of gravitational pull on an object.

At the same location, two objects with *identical masses* have *identical weights* (gravity pulls them equally).

Thus masses of objects determined by comparing the weight of the object to the weight of a known reference.

MAR

Measuring Length

The Meter (m) is the standard measure of length or distance in both SI and metric system. One meter is 39.37 inches.

Centimeter (cm; $^1/_{100}$ m) and millimeter (mm; $^1/_{1000}$ m) commonly used for most measurements in chemistry and medicine.

MAR

Measuring Volume

Volume is the amount of space occupied by an object.

SI unit for volume is the cubic meter (m^3)

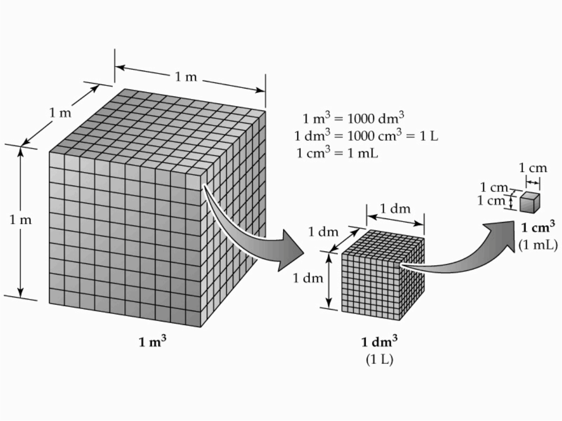
Liter (L) is commonly used in chemistry.

1 L = 0.001 m^3 = 1000 mL

A milliliter is often called a cubic centimeter

1 mL = 1 cm^3

MAR



MAR

Scientific Notation

Scientific notation used by scientists to express very large and very small numbers in a compact fashion.

To express a number in scientific notation we rewrite the quantity as a number (between 1 and 9) multiplied by 10 raised to a power (exponent) that tells us how we moved the decimal point.

- Multiply the number by 10^0. (*Remember* $10^0 = 1$)
- Move the decimal point to give a number between 1 and 10.
- Every time we shift the decimal point to the <u>left</u> by one place we <u>increase</u> the value of the exponent by one.
- Every time we shift the decimal point to the <u>right</u> by one place we <u>reduce</u> the value of the exponent by one.

$215. = 2.15 \times 10^2$

Decimal point is moved two places to the left, so exponent is 2.

MAR

Scientific Notation

Example: Write 120,000 in scientific notation.

$120{,}000 = 120{,}000 \times 10^0 = 1.2 \times 10^5$

Example: Write 0.0000012 in scientific notation.

$0.0000012 = 0.0000012 \times 10^0 = 1.2 \times 10^{-6}$

Scientific Notation

To express a scientific notation number as a non-exponential "regular" number:

- Move the decimal point the same number of places as the value of the exponent and eliminate the exponential part of the number.
- If the exponent is positive, we move the decimal to the right, to the same number of places as the value of the exponent. (The result should be a number greater than 1.)
- If the exponent is negative, we move the decimal to the left, to the same number of places as the value of the exponent. (The result should be a number less than 1.)

$1.56 \times 10^{-8} = 0.000\,000\,015\,6$

Negative exponent of –8,
so decimal point is moved to the left eight places.

Scientific Notation

Example: Write 1.23 x 10^6 in non-exponential form.

$1.23 \times 10^6 = 1{,}230{,}000$

Example: Write 1.11 x 10^{-5} in non-exponential form.

$1.11 \times 10^{-5} = 0.0000111$

Remember: If we make the exponent larger we must make the number part smaller, and if we make the exponent smaller we must make the number part larger.

Calculations Using Scientific Notation on Your Calculator

Let's see how you are at using your calculators. Try the following and don't forget about cancelling units where appropriate. Record your answers in scientific notation, rounded to one digit past the decimal. (**Rounding rule: 5 or bigger, round up**.)

1. $(1.5 \times 10^5 \text{ in}^2)(1.2 \times 10^{-2} \text{ in}) = ?$

(It saves time to use your exponent button. EE, exp, 10^x)

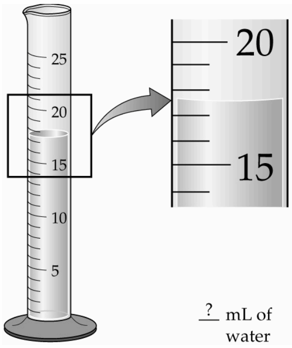
1.5EE5x1.2EE(-)2 [Enter] = 1800 in^3 = 1.8×10^3 in^3 *1800 exact*

2. 4.3×10^5 ft / 5.1×10^{-6} ft = ? (try this yourself!)

$= 8.4 \times 10^{10}$ *8.43137.... E10*

Measurement and Significant Figures

Every experimental measurement, no matter how precise, has a degree of uncertainty because there is a limit to the number of digits that can be determined.



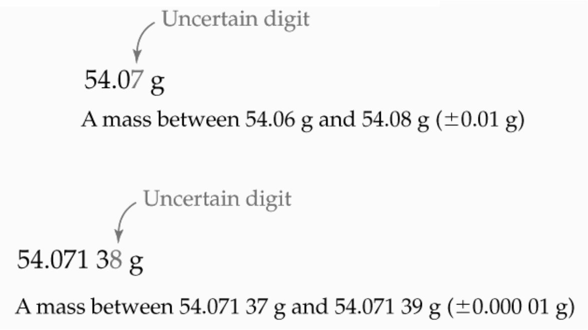
Measurement and Significant Figures

To indicate the precision of the measurement, the value recorded should use all the digits known with certainty *plus* one additional estimated digit ("doubtful digit") that usually is considered *uncertain* by plus or minus 1 (± 1)

The total number of digits used to express such a measurement is called the number of ***significant figures***.

Example: The quantity 65.07 g has four significant figures and 7 is the "doubtful digit"

Measurement and Significant Figures



MAR

Rules for Determining Significant Figures

1. Zeroes in the middle of a number are significant. 69.08 g has four significant figures, 6, 9, 0, and 8.
2. Zeroes at the beginning of a number are not significant. 0.0089 g has two significant figure, 8 and 9.
3. Zeroes at the end of a number and after the decimal points are significant. 2.50 g has three significant figures 2, 5, and 0. 25.00 m has four significant figures 2, 5, 0, and 0.

MAR

Significant Figures often abbreviated as "sig figs"

Rules for Determining Significant Figures

4. Zeroes at the end of a number and before an implied decimal points may or may not be significant. 1500 kg may have two, three, or four significant figures. Zeroes here may be part of the measurements or for simply to locate the unwritten decimal point.

MAR

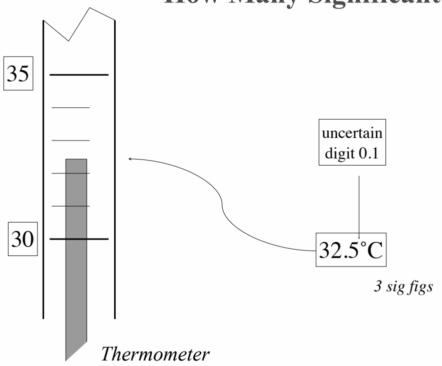
Test Yourself: How Many Significant Figures?

94.072 g
0.0834 cm
0.02907 mL
138.200 m
23,000 kg

23,000. kg

MAR

How Many Significant Figures?

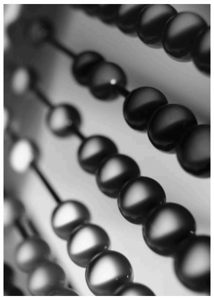


MAR

Rounding off Numbers

Often calculators produce large numbers as a result of a calculation *although* the number of significant figures is good only to a few numbers, less than the calculator has produced

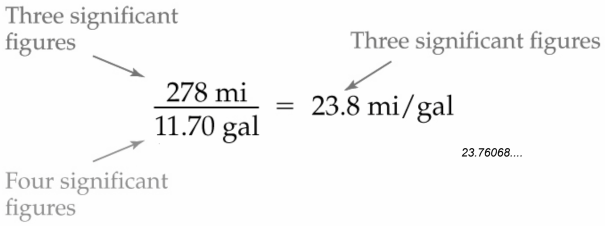
In this case the large number may be rounded off to a smaller number *keeping only significant figures*.



MAR

Rules for Rounding off Numbers

Rule 1 (For multiplication and divisions): The answer can't have more significant figures than either of the original numbers.



Three significant figures

Three significant figures

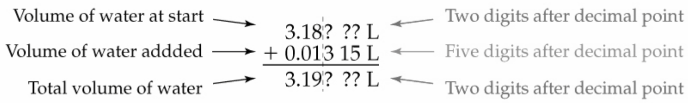
$$\frac{278\ \text{mi}}{11.70\ \text{gal}} = 23.8\ \text{mi/gal}$$

23.76068....

Four significant figures

Rules for Rounding off Numbers

Rule 2 (For addition and subtraction): The number can't have more digits after the decimal point than either of the original numbers.



Volume of water at start → 3.18? ?? L ← Two digits after decimal point

Volume of water addded → + 0.013 15 L ← Five digits after decimal point

Total volume of water → 3.19? ?? L ← Two digits after decimal point

Rules for Rounding off Numbers

Rule 3: Once you decide how many numbers to keep, you *may* need to round off your answer:

If the first digit you remove is between 0 and 4, drop it and all remaining digits.

If the first digit you remove is between 5 and 9, round the number up by adding 1 to the digit to the left of the one you drop

Example: **2.4271** becomes **2.4** when rounded to two significant figures

Example: **4.5816** becomes **4.6** when rounded to two significant figures

Factor-Label Method of Unit Conversions

Quantities measured in the lab usually have **units (labels)** which tell us the type of measurement made.

For example:

5.2 cm - the unit (cm) tells us the type of measurement made is length.
16.237 g - the unit (g) tells us the type of measurement made is mass.

Often we must convert one kind of unit for a measurement to a different kind. For example, we may need to convert 28 inches into a certain number of feet. The **factor-label** method (also known as the *dimensional analysis* method) uses **conversion factors** and units (**labels**) to solve problems of this type.

Factor-Label Method of Unit Conversions

Conversion factors are fractions that relate two kinds of units. One way in which they may be obtained is from equalities.

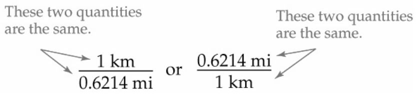
For example: 12 in = 1 ft is an equality which leads to two equivalent fractions (conversion factors) generated by dividing one side of the equality by the other side.

$$\frac{12\ \text{in}}{1\ \text{ft}} \qquad \frac{1\ \text{ft}}{12\ \text{in}}$$

Another common conversion factor: there are 4 quarters in a dollar ($):

$$\frac{4\ \text{quarters}}{1\ \$} \qquad \frac{1\ \$}{4\ \text{quarters}}$$

And:



These two quantities are the same.

These two quantities are the same.

$$\frac{1\ \text{km}}{0.6214\ \text{mi}} \text{ or } \frac{0.6214\ \text{mi}}{1\ \text{km}}$$

Factor-Label Method of Unit Conversions

And yet another common example:

60 min = 1 hr is an equality which leads to two equivalent conversion factors.

$$\frac{60\ \text{min}}{1\ \text{hr}} \qquad \frac{1\ \text{hr}}{60\ \text{min}}$$

Other forms : $\frac{60\ \text{min}}{\text{per hr}}$ = 60 min/hr = $\frac{60\ \text{min}}{1\ \text{hr}}$

When you are new to the factor-label method, it is most helpful to use the form that has a numerator and denominator term (and not 60 min/hr)

Some conversion factors are considered *exact* and have *unlimited sig figs,* but most conversion factors obey sig fig rules.

When solving a problem, set up an equation so that *all unwanted units cancel*, leaving only the desired unit. *For example*, we want to find out how many kilometers are there in 26.22 miles. We will get the correct answer if we multiply 26.22 mi by the conversion factor km/mi.

$$\underset{\substack{\uparrow \\ \text{Starting} \\ \text{quantity}}}{26.22\ \cancel{\text{mi}}} \times \underset{\substack{\uparrow \\ \text{Conversion} \\ \text{factor}}}{\frac{1\ \text{km}}{0.6214\ \cancel{\text{mi}}}} = \underset{\substack{\uparrow \\ \text{Equivalent} \\ \text{quantity}}}{42.20\ \text{km}}$$

42.195043....

MAR

Some **Exact Conversions**

Length
1 km = 1000 m = 10^5 cm = 10^{12} nm
12 in = 1 ft   5280 ft =1 mile
1 in = 2.54 cm

Volume
1 cm^3 = 1 mL   1000 mL = 1 L

Mass
1 g = 1000 mg   1 kg = 1000 g

These conversions have ***unlimited*** sig figs by definition.
Most other conversions inexact… and follow sig fig rules!

MAR

Test yourself: How many hours in 3.5 weeks?

MAR

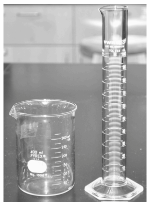
Test yourself: How many quarters will a tourist need to travel 555 km? Car: 22 miles per gallon, gas: $1.37/gallon, 1.61 km = 1 mile

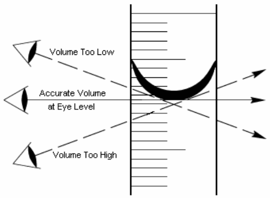
MAR

How do we measure the volume of a liquid?

volumetric flasks

Beaker (left), graduated cylinder (right)





read volume from bottom of meniscus at eye level

MAR

Density

Density relates the mass of an object with its volume.
Density is usually expressed in:

- Gram per cubic centimeter (g/cm^3) (solids)
- Gram per milliliter (g/mL) (liquids)

$$\text{Density} = \frac{\text{Mass (g)}}{\text{Volume (mL or cm}^3\text{)}}$$

MAR

Test yourself: Mercury has a density of 13.6 g/mL. How many L of Hg are there in 42.7 kg of Hg?

MAR

Measuring Temperature

Temperature, the measure of how hot or cold an object is, is commonly reported either in Fahrenheit (^{o}F) or Celsius (^{o}C). The SI unit of temperature is, however, the Kelvin (K).

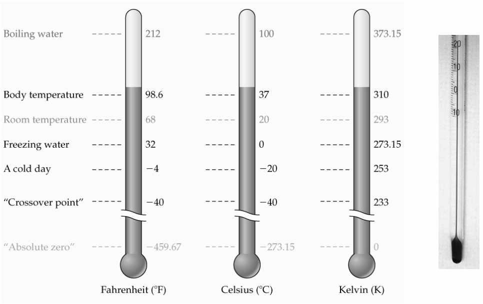
Kelvin temperatures are ***always positive*** and they do not use the degree (^{o}) symbol.

Kelvin used in calculations, Celsius in the lab.

Temperature in K = Temperature in ^{o}C + 273.15

Temperature in ^{o}C = Temperature in K - 273.15

MAR



Comparison of the Fahrenheit, Celsius, and Kelvin Scales

MAR

Converting between Fahrenheit and Celsius scales is similar to converting between different units of length or volume.

The following formulas can be used for the conversion:

$^{o}F = 1.8 \text{ x } ^{o}C + 32\ ^{o}F$

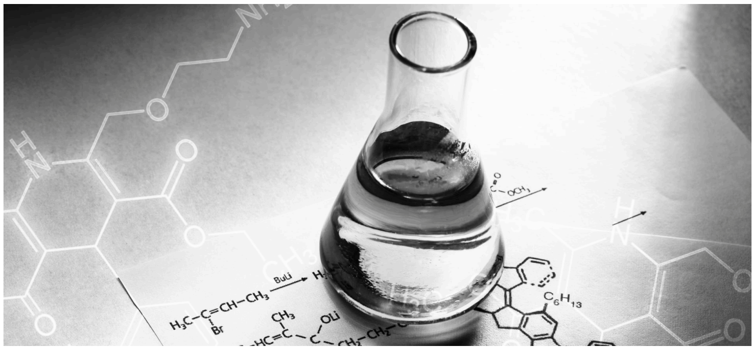
$^{o}C = (^{o}F - 32\ ^{o}F) / 1.8$

MAR

Test yourself: Mars often has temperatures around -70. °C. Express this in K and °F.

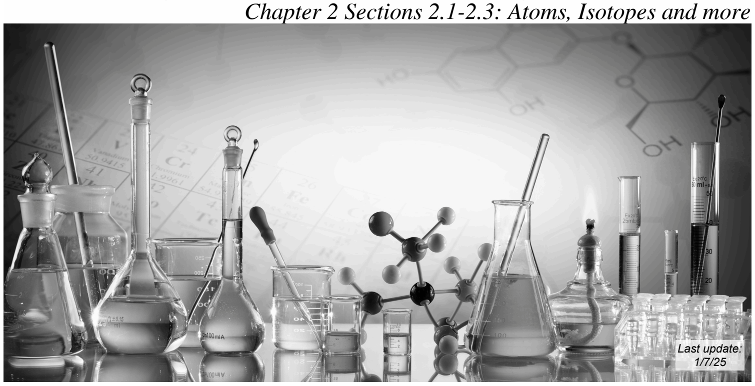
MAR

End of Chapter 1



Chemistry 151: Basic Chemistry

Chapter 2 Sections 2.1-2.3: Atoms, Isotopes and more



Basic Terms of Chemistry

Matter: Anything that has mass and occupies space – things you can see, touch, taste, or smell.

Property: a characteristic that can be used to describe a substance.

Size, color, temperature are familiar properties of matter. Less familiar properties include:

Chemical composition: what matter is made of.

Chemical Reactivity: how matter behaves, *reactions*.

MAR

Physical and Chemical Change

A Physical Change does not alter the chemical makeup of a substance. Change is reversible.

Example: Melting of solid ice; only change in form takes place and change is reversible.

A Chemical Change alters chemical composition of a substance. Change is irreversible.

Example: Rusting of iron; iron combines with oxygen and produces a new substance (rust).

MAR

States of Matter

Matter exist in three forms: *solid*, *liquid*, and *gas*.

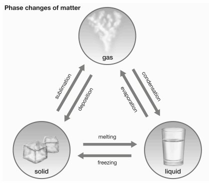
Solids have definite shape and volume.

Liquids have definite volume but changes shape to fill containers.

Gases have neither definite volume or definite shape.

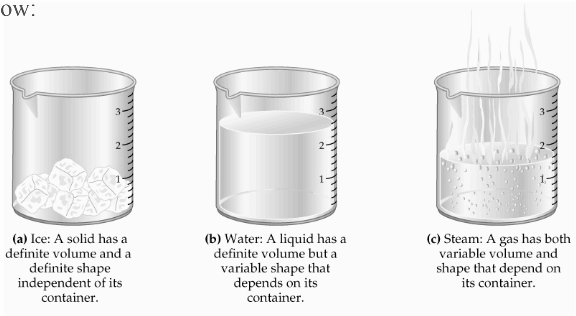
Most substances, such as **water**, can exist in all three states depending on the temperature.

The conversion of a substance from one state into another is known as *change of state*.



MAR

The **solid, liquid** and **gaseous** states of water are shown below:



(a) Ice: A solid has a definite volume and a definite shape independent of its container.

(b) Water: A liquid has a definite volume but a variable shape that depends on its container.

(c) Steam: A gas has both variable volume and shape that depend on its container.

MAR

More on the Kinetic Molecular Theory (KMT) of Matter in CH 221!

Classification of Matter

Pure Substance: Uniform in its chemical composition and properties. Sugar (a compound) and water (compound) are pure substances.

Elements and **Compounds** can be pure.

Mixture: Composition and properties may vary. Different amounts of sugar dissolved in water will determine sweetness of water.

Mixtures can be **heterogeneous** (single phase) or **homogeneous** (single phase)

Sugar water is a homogeneous mixture, sand is a heterogeneous mixture

MAR

Elements and Compounds

Elements cannot be broken down chemically into simpler substances, "building blocks" of nature.

Hydrogen, oxygen, and nitrogen are example of elements.

Chemical Compounds can be broken down into elements or other compounds.

Water is a chemical compound since it can be broken down into hydrogen and oxygen.

MAR

Mixtures and compounds contain more than one substance. What's the difference?

Mixture:

$$\underset{\text{(variable proportions)}}{\text{Sugar water}} \xrightarrow[\text{change}]{\text{physical}} \underset{\text{compound}}{\text{Sugar}} + \underset{\text{compound}}{\text{Water}}$$

Mixtures broken down to compounds or elements by physical changes

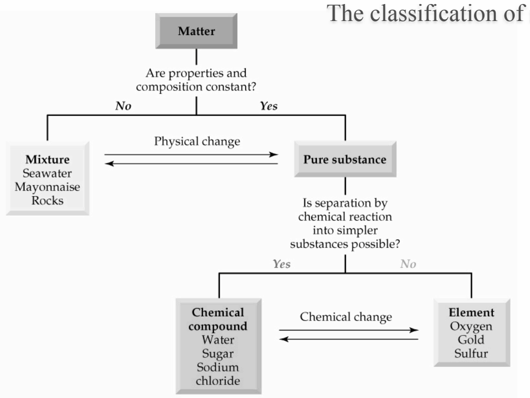
Compound:

$$\underset{\text{(fixed proportions)}}{\text{Water}} \xrightarrow[\text{change}]{\text{chemical}} \underset{\text{element}}{\text{hydrogen}} + \underset{\text{element}}{\text{oxygen}}$$

MAR

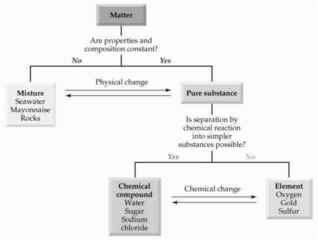
Compounds broken down to elements by chemical changes

The classification of matter scheme:



MAR

Test yourself:



pizza
Coke
water
silicon
iron
rust

MAR

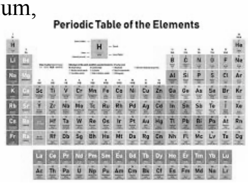
Chemical Elements and Symbols

Approximately 118 Elements are known - they are listed on the periodic table.

Only 90 of these elements occur naturally, remaining elements synthesized in lab.

Some familiar elements are iron, tin, carbon, oxygen, hydrogen, sulfur, etc.

Some possibly unfamiliar elements are niobium, rhodium, thulium, californium, etc.



MAR

Chemical Symbols

Each element has its own unique *symbol*.

One or *two* letter symbols are used to represent elements.

First letter is always *capitalized* and the second letter is always a *lower case*.

Some symbols came from elements' modern names such as 'H' for hydrogen, 'O' for oxygen, 'N' for nitrogen, etc.

MAR

Chemical Symbols

A few symbols for elements from their *Latin* names. *Example:* 'Na' for sodium from Latin *Natrium*.

Naturally occurring elements are not equally abundant. Oxygen and silicon together: 75% of earth's crust.

Chemical Formula: A notation for a chemical compound using element symbols and subscripts to show how many atoms of each element are present.

MAR

The formula for water is H_2O.

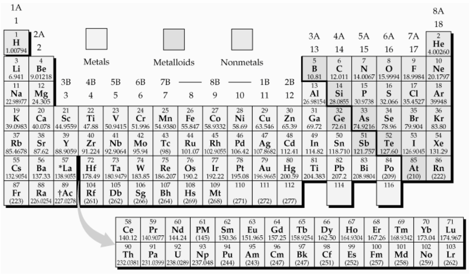
H_2O indicates that two hydrogens and one oxygen combined together to produce water.

Every formula described similarly

$$\underbrace{H_2O}_{\substack{\text{2 H atoms} \\ \text{1 O atom}}} \qquad \underbrace{CH_4}_{\substack{\text{1 C atom} \\ \text{4 H atoms}}} \qquad \underbrace{C_{12}H_{22}O_{11}}_{\substack{\text{12 C atoms} \\ \text{22 H atoms} \\ \text{11 O atoms}}}$$

MAR

Elements and the Periodic Table



Metals, nonmetals and metalloids appear in distinct places on the periodic table

MAR

Metals (left side)

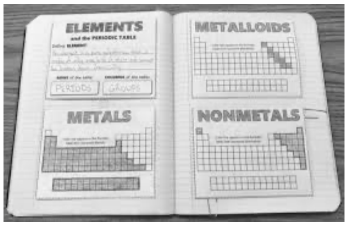
- Solids at room temperature (except Hg)
- Good conductor of heat & electricity
- Malleable, give up electrons

Nonmetals (right side)

- Eleven gases, five solids, one liquid (Br)
- Like to absorb electrons generally

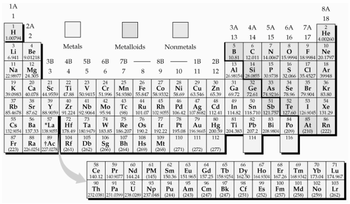
Metalloids (between)

- Properties between metals and nonmetals
- Used in semi-conductors



MAR

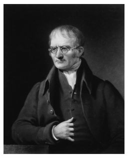
Test yourself:



Metal, Metalloid or Nonmetal:

Li
Au
Si
Se
Cl
Ne

MAR


John Dalton

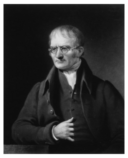
John Dalton's Atomic Theory

Chemistry founded on four fundamental assumptions about **atoms** and **matter** which make up the modern **Atomic Theory**:

1. All matter is composed of atoms.
2. The atoms of an element differ from the atoms of all other elements.
3. Chemical compounds consist of atoms combined in specific ratios.
4. Chemical reactions change only the way the atoms are combined in compounds; the atoms themselves are unchanged.

MAR

John Dalton's Atomic Theory



John Dalton

Atoms are the smallest pieces of elements.

You can divide an element down to the atom... but if you divide an atom, it will no longer be the same element.

Molecules are the smallest pieces of compounds.

You can divide compounds down to the molecule... but if you divide a molecule, it will break into individual atoms (or smaller molecules.)

MAR

Atomic Theory

Atoms are composed of tiny **subatomic particles** called **protons**, **neutrons**, and **electrons**.

Since the masses of atoms are so small, their masses are expressed on a *relative mass scale*. That is, one atom is assigned a mass, and all others are measured relative to it.

Relative atomic mass scale based on carbon atoms with 6 protons and 6 neutrons. This carbon atom is assigned a mass of *exactly* 12 atomic mass units (**amu**). **1 amu = 1.66 * 10^{-24} g**

Mass of proton = 1.007 amu

Mass of oxygen = 16.00 amu

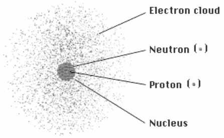
MAR

Atomic Theory

Subatomic particles not distributed randomly throughout atoms.

Protons and **neutrons** packed closely together in a dense core called the **nucleus**.

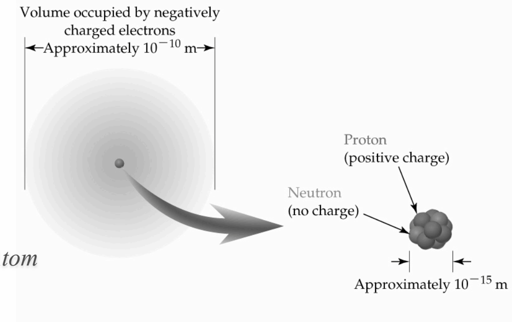
Electrons move about rapidly around core through a large, mostly empty volume of space in atom.



MAR

Diameter of a <u>nucleus</u> is only about 10^{-15} m.

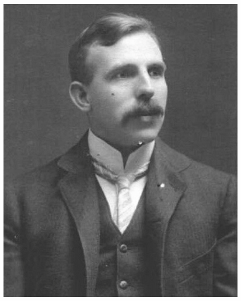
Diameter of an <u>atom</u> is only about 10^{-10} m.



The Structure of an Atom

MAR

The modern view of the atom was developed by Ernest Rutherford in 1910.

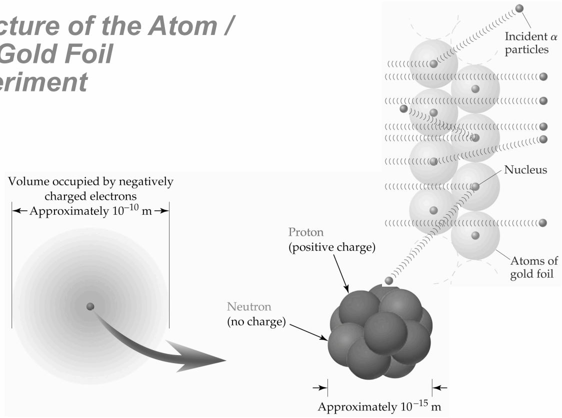


Rutherford Experiment: Nuclear Atom

Low density atom with a highly dense, positively charged nucleus

MAR

Structure of the Atom / The Gold Foil Experiment

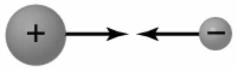


MAR

Attraction / Repulsion

Structure of atoms determined by an interplay of different **attractive** and **repulsive forces**.

Unlike charges attract - the *negatively charged electrons* held close to nucleus by attraction to *positively charged protons*

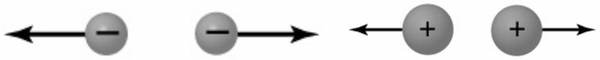

Protons and electrons attract one another

MAR

Attraction / Repulsion

Like charges repel each other - *negatively charged electrons* try to get as far apart as possible

Positively charged protons in nucleus also repel, but they are held together by a unique attraction called *nuclear strong force (Chemistry 222)*


Electrons repel one another

Protons repel one another

MAR

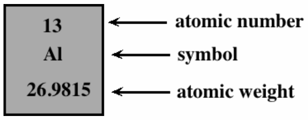
Element and Atomic Number

Atomic Number (Z): Number of protons in an atom

Elements defined by number of protons in the nucleus.

Atoms are neutral overall with no net charge; hence, number of positive protons equals number of negative electrons in the atom.

Mass Number (A): The total number of protons *and* neutrons in an atom.



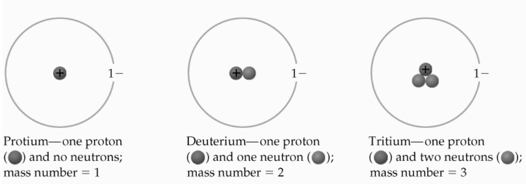
MAR

Isotopes and Atomic Weight

Isotopes are atoms with identical atomic numbers (Z) but different mass numbers (A)

Protium, deuterium, and tritium are isotopes of hydrogen.

- Protium: one proton (Z=1) and no neutrons (A=1)
- Deuterium: one proton (Z=1) and one neutron (A=2)
- Tritium: one proton (Z=1) and two neutrons (A=3)



Protium—one proton (●) and no neutrons; mass number = 1

Deuterium—one proton (●) and one neutron (●); mass number = 2

Tritium—one proton (●) and two neutrons (●); mass number = 3

MAR

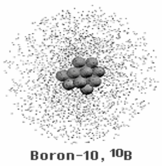
Atomic and Mass Numbers

Atomic Number, Z

Z = # protons *(defines element)*

Mass Number, A

A = # protons + # neutrons


Boron-10, ^{10}B

A boron atom can have

A = 5 p + 5 n = 10 amu

Method to display A, Z and element symbol:

$$\begin{matrix} A \longrightarrow 10 & \\ & B \\ Z \longrightarrow 5 & \end{matrix}$$

MAR

Hydrogen Isotopes

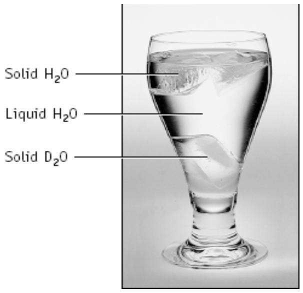
Hydrogen has *three* isotopes

$^{1}_{1}H$ **1 proton and 0 neutrons, protium**

$^{2}_{1}H$ **1 proton and 1 neutron, deuterium**

$^{3}_{1}H$ **1 proton and 2 neutrons, tritium**

radioactive



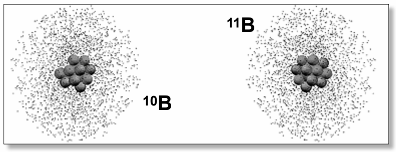
MAR

Isotopes Overview

Atoms of the same element (same Z) but different mass number (A).

Boron-10 has 5 p and 5 n: $^{10}_{5}B$

Boron-11 has 5 p and 6 n: $^{11}_{5}B$



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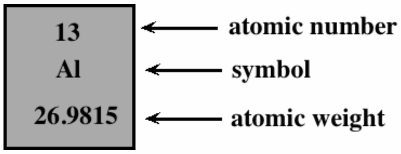
Atomic Weight: The weighted average mass of an element's atoms in a large sample that includes all naturally occurring isotopes of that atom.

Atomic number and atomic weight displayed in periodic table *(but not mass number!)*



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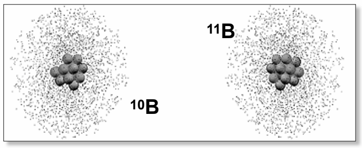
Isotopes



Because of the existence of isotopes, the mass of a collection of atoms has an average value.

Average mass = ATOMIC WEIGHT

Boron is 20% ^{10}B and 80% ^{11}B. That is, ^{11}B is 80 percent abundant on earth.

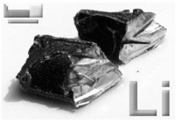
For boron atomic weight

= 0.20 (10 amu) + 0.80 (11 amu) = 10.8 amu

MAR

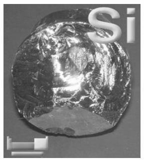
Isotopes & Atomic Weight

Because of the existence of isotopes, the mass of a *collection* of atoms has an average value.



^{6}Li = 7.5% abundant and ^{7}Li = 92.5%

Atomic weight of Li = ______________

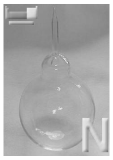


^{28}Si = 92.23%, ^{29}Si = 4.67%, ^{30}Si = 3.10%

Atomic weight of Si = ______________

MAR

Isotopes



Example: **Nitrogen has two main isotopes, ^{14}N (14.0031 amu, 99.6299%) and ^{15}N (15.0001 amu, 0.3701%). Calculate the average atomic mass.**

Solution

Average atomic mass =

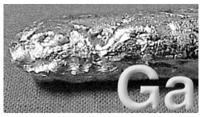
= (0.996299*14.0031) + (0.003701*15.0001)

= 13.9512745 + 0.05551537

= 14.0068 amu

MAR

Isotopes



Example: **Gallium has two main isotopes, ^{69}Ga (68.9257 amu) and ^{71}Ga (70.9249 amu) with an average atomic mass of 69.723. Calculate the % abundance of each isotope.**

Solution

Average atomic mass =

69.723 = *x*(^{69}Ga)*68.9257 + *y*(^{71}Ga)*70.9249

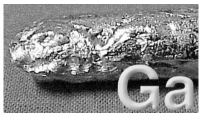
but also

1 = *x*(^{69}Ga) + *y*(^{71}Ga) *(2 percentages equal 100%)*

so y(^{71}Ga) = 1 - x(^{69}Ga)

MAR

Isotopes



Example: **Gallium has two main isotopes, ^{69}Ga (68.9257 amu) and ^{71}Ga (70.9249 amu) with an average atomic mass of 69.723. Calculate the % abundance of each isotope.**

Solution

69.723 = *x*(^{69}Ga)*68.9257 + *y*(^{71}Ga)*70.9249, *or*

69.723 = x*68.9257 + (1 - x)*70.9249

69.723 = x*68.9257 + 70.9249 - 70.9249x

Solve for x, get:

***x*(^{69}Ga) = 0.6012 (60.12%)**

***y*(^{71}Ga) = 1 - x = 0.3988 (39.88%)**

MAR

Isotopes

Antimony has two main isotopes:

^{121}Sb (120.9038 amu, 57.20%) *and*

^{123}Sb (122.9042 amu, 42.80%)

Average atomic mass of Sb: **121.760**

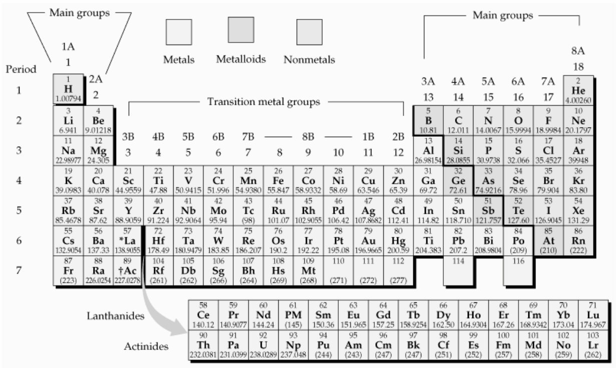
Will you have <u>one atom</u> of antimony with 121.760 amu?

No!

One atom of antimony will have a mass of 120.9038 amu 57.20% of the time

One atom of antimony will have a mass of 122.9042 amu 42.80% of the time

MAR



Period	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	9	10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.00794																	2 He 4.00260
2	3 Li 6.941	4 Be 9.01218											5 B 10.81	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.1797
3	11 Na 22.98977	12 Mg 24.305											13 Al 26.98154	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39948
4	19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
5	37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.41	49 In 114.82	50 Sn 118.710	51 Sb 121.757	52 Te 127.60	53 I 126.9045	54 Xe 131.29
6	55 Cs 132.9054	56 Ba 137.33	57 *La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.9665	80 Hg 200.59	81 Ti 204.383	82 Pb 207.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.0254	89 †Ac 227.0278	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (269)	109 Mt (268)	110 (271)	111 (272)	112 (277)		114		116		

Lanthanides	58 Ce 140.12	59 Pr 140.9077	60 Nd 144.24	61 PM (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.50	67 Ho 164.9304	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.967
Actinides	90 Th 232.0381	91 Pa 231.0399	92 U 238.0289	93 Np 237.048	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

MAR

The Periodic Table

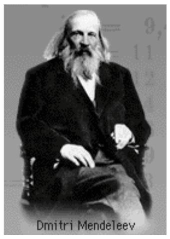
The Periodic Table

Beginning in upper left corner, elements are arranged by increasing atomic number

Seven horizontal rows called ***periods***

Eighteen vertical columns called ***groups***.

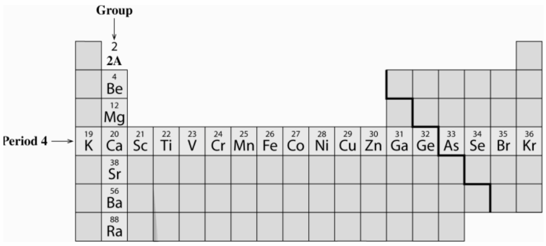
Elements in a given group have similar chemical properties (i.e. lithium, sodium, potassium, etc. in group 1A have similar properties)



Dmitri Mendeleev

MAR

Groups and Periods



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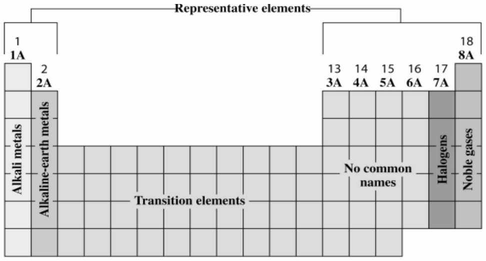
Groups on the Periodic Table

Several groups of elements are known by common names.



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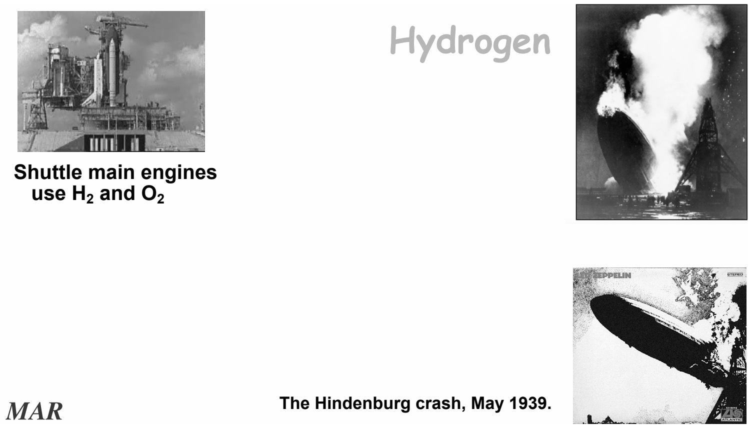

Hydrogen

Shuttle main engines use H_2 and O_2

The Hindenburg crash, May 1939.

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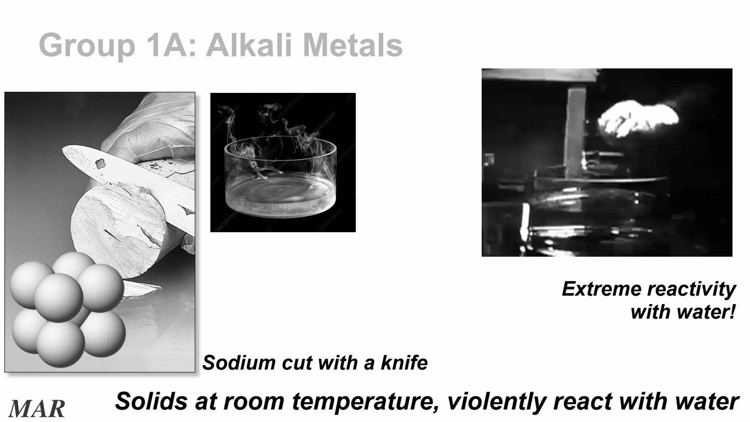


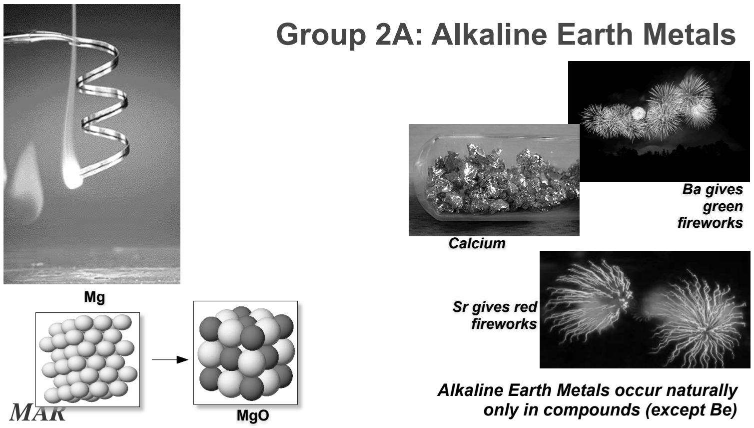
Group 1A: Alkali Metals

Sodium cut with a knife

Extreme reactivity with water!

Solids at room temperature, violently react with water

MAR



Group 2A: Alkaline Earth Metals

Mg

MgO

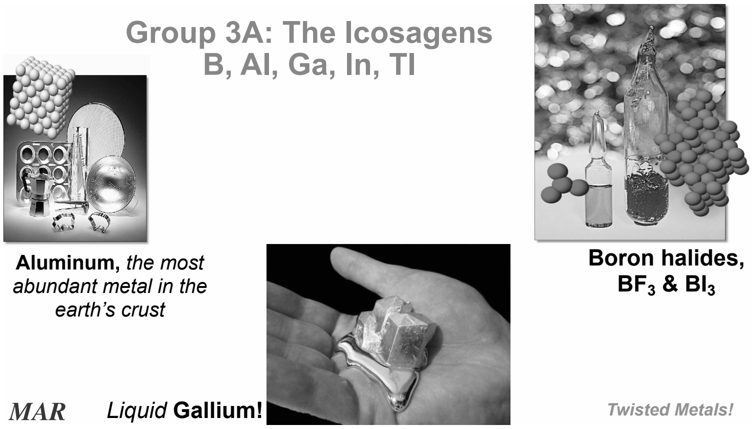
Calcium

Ba gives green fireworks

Sr gives red fireworks

Alkaline Earth Metals occur naturally only in compounds (except Be)

MAR



Group 3A: The Icosagens
B, Al, Ga, In, Tl

Aluminum, *the most abundant metal in the earth's crust*

Liquid **Gallium!**

Boron halides, BF_3 & BI_3

Twisted Metals!

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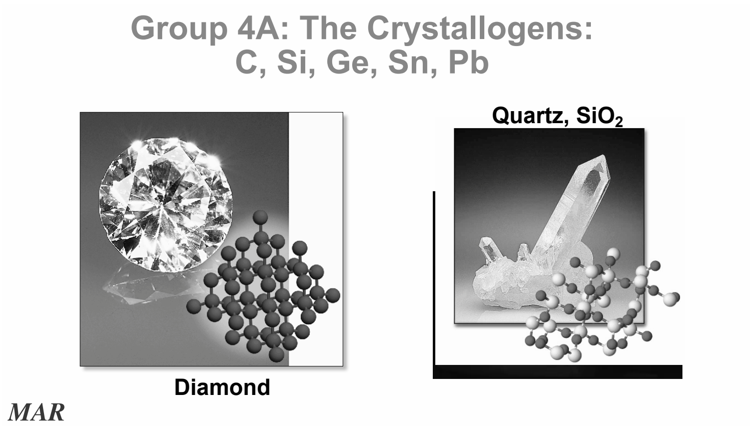

Group 4A: The Crystallogens:
C, Si, Ge, Sn, Pb

Diamond

Quartz, SiO_2

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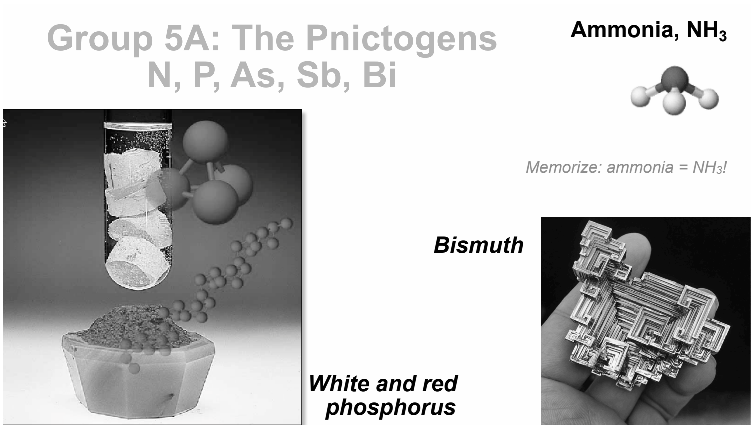


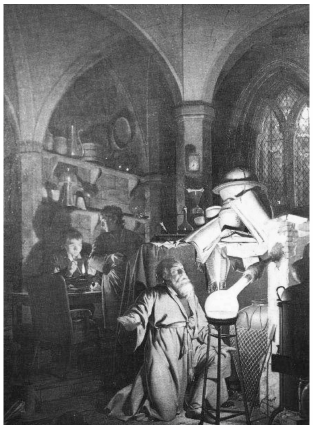
Group 5A: The Pnictogens
N, P, As, Sb, Bi

Ammonia, NH_3

Memorize: ammonia = NH_3!

Bismuth

White and red phosphorus



Phosphorus

Red and white phosphorus ignite in air to make P_4O_{10}

Phosphorus first isolated by Brandt from urine (!) in 1669

Most chemists' jobs are not so "demanding"!!!

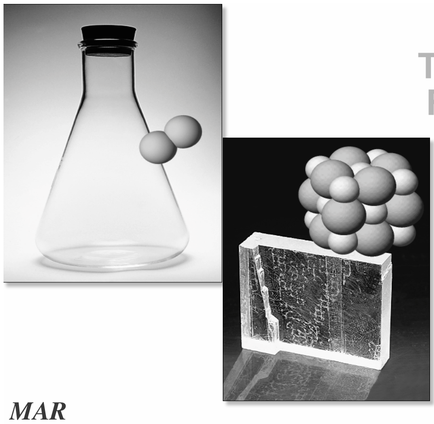
Group 6A: The Chalcogens O, S, Se, Te, Po

Sulfuric acid dripping from a cave in Mexico

Sulfur from a volcano

MAR

Group 7A: The Halogens F, Cl, Br, I, At



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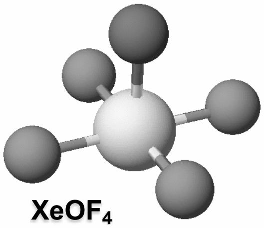
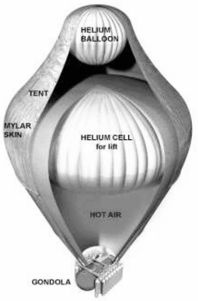
Group 8A: Noble Gases He, Ne, Ar, Kr, Xe, Rn

All gases at room temperature; considered unreactive until 1962



$XeOF_4$



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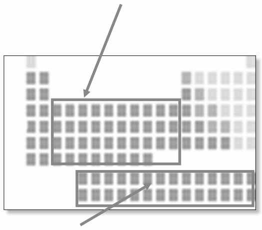
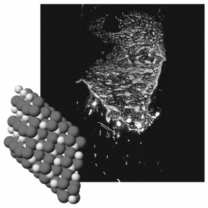
Transition Metals



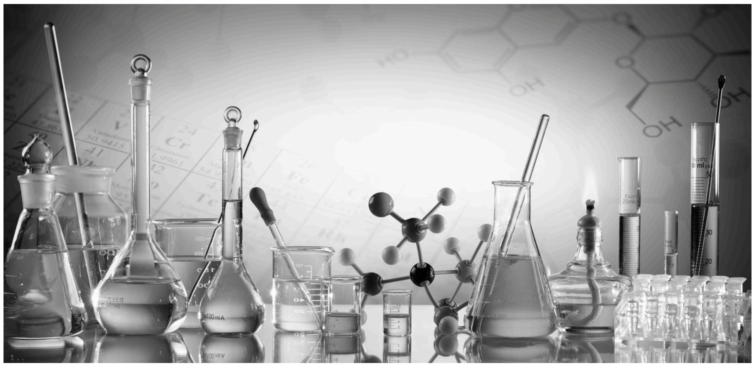
Lanthanides and actinides



Iron in air gives iron(III) oxide

MAR

End of Chapter 2 (2.1-2.3)



Chemistry 151: Basic Chemistry

Chapter 4 (Section 4.3): Nomenclature

Last update: 1/10/25

Time For a (*relevant*) Joke!

Two chemists walk into a bar.
The first chemist says, "I'll have some H Two O"
A clear liquid in a glass arrives...
They drink it down... very satisfying.

i.e. H_2O, water

The second chemist says, "I'll have some H Two O Too"
A clear liquid in a glass arrives...
They drink it down....
...and die!

i.e. H_2O_2

H_2O = **water**, good to drink!
H_2O_2 = **hydrogen peroxide**, looks like water, dangerous / deadly to drink

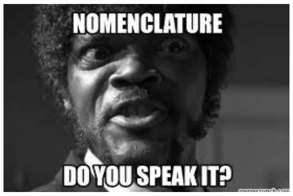
One extra atom affects the reactivity!
Nomenclature very important!

MAR

Nomenclature

Nomenclature: a set of rules used to generate names for chemical compounds - or, being able to "talk the talk" of chemistry

Important to describe H_2O (essential to life) versus H_2O_2 (deadly oxidizing agent) - one atom (more or less) makes a huge difference



This is arguably the most important chapter of CH 151!

MAR

Compounds and Molecules

COMPOUNDS are a combination of 2 or more elements in definite ratios by mass.

The character of each element is lost when forming a compound.

MOLECULES are the smallest unit of a compound that retains the characteristics of the compound.

MAR

Chemical Bond

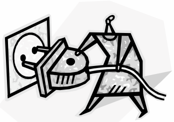
008

Bonding, the way **atoms** are attracted to each other to form **molecules**, determines nearly all of the chemical properties. We shall see later that the number "8" is very important to chemical bonding.

Bonding can be **ionic** or **covalent**.

MAR

Ions



Atoms are electrically neutral because
  number of protons = number of electrons

By gaining or losing electrons an atom can be converted into a charged particle called an ***ion***.

Loss of one or more electrons gives positively charged ion called a ***cation***.

Gaining one or more electrons gives negatively charged ion called a ***anion***.

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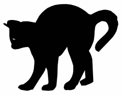
IONS AND IONIC COMPOUNDS

CATIONS have protons > electrons

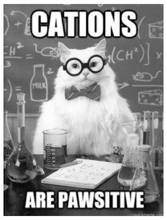


ANIONS have electrons > protons

Remember:

CATS have PAWS

CATions are PAWSitive



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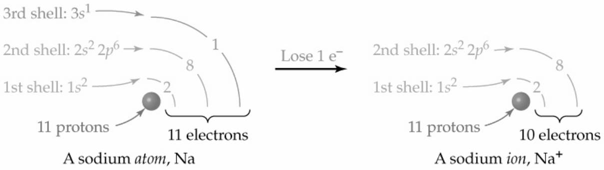
Cations

The symbol for a cation is written by adding a positive charge as a superscript to the symbol for the element.

For example, Na loses an electron to make the sodium cation (Na^+).



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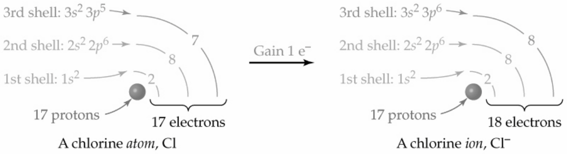
Anions

The symbol for a anion is written by adding a negative charge as a superscript to the symbol for the element.

For example, Cl gains an electron to make the chloride anion (Cl^-).



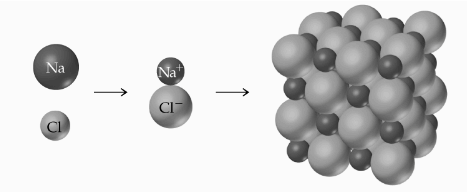
MAR

Ionic Bonds

Opposite electrical charges *attract*

When sodium combines with chlorine, sodium transfers electron to chlorine forming Na^+ and Cl^- ions.

The oppositely charged Na^+ and Cl^- ions are held together by a *ionic bond*, making an *ionic compound*.



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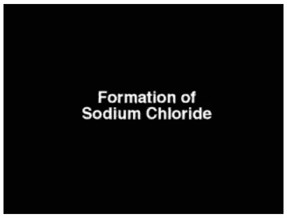
Formation of NaCl



Formation of Sodium Chloride

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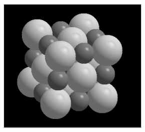
Ionic Compounds

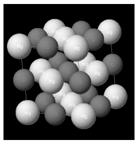
Ionic compounds *usually* form crystalline solids

Ions vary in size and charge.

Ionic compounds have high melting and boiling points.



NaCl, Na^+ and Cl^-, m.p. 804 ^oC



MgO, Mg^{2+} and O^{2-} m.p. 2800 ^oC

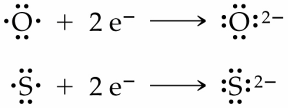
MAR

Ions of Some Common Elements

Metals of group 1A and 2A form *only* +1 and +2 ions. Ions of these elements all have a noble gas configuration through *electron loss* from their outermost shell.

Group 6A and 7A elements attain noble gas configuration by *gaining* 1 or 2 electrons.

Group 6A:



"noble gas configuration" means 8 electrons

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Ions and the Octet Rule

Octet Rule: Main group elements undergo reactions that leave them with 8 valence electrons or a noble gas configuration - **isoelectronic** (same number of electrons) with noble gases.

All noble gases (except helium) have 8 electrons in their valence shell.

For example, in NaCl, Na^+ and Cl^- have the following electron configurations:

$$\underset{1s^2\,2s^2\,2p^6\,3s^1}{\text{Na}} \; + \; \underset{1s^2\,2s^2\,2p^6\,3s^2\,3p^5}{\text{Cl}} \longrightarrow \underset{\underbrace{1s^2\,2s^2\,2p^6}_{\text{Neon configuration}}}{\text{Na}^+} \; + \; \underset{\underbrace{1s^2\,2s^2\,2p^6\,3s^2\,3p^6}_{\text{Argon configuration}}}{\text{Cl}^-}$$

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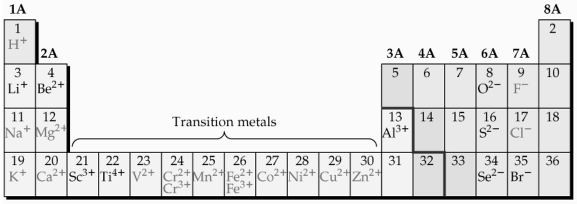
Common ions formed by elements in the first four periods



Groups IA - IIIA: ion usually gets a positive charge equal to the group number
Groups VA - VIIA: ion usually gets a negative charge equal to the group number minus eight
Ex: Aluminum makes the Al^{3+} ion
Ex: Nitrogen makes the N^{3-} ion

MAR

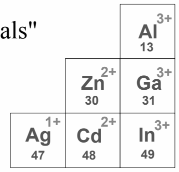
Naming Fixed Charge Cations

Main group metal cations (Groups 1A, 2A, and "the stairs") named by identifying the metal, followed by the word "ion":

K^+	Potassium ion
Mg^{2+}	Magnesium ion
Al^{3+}	Aluminum ion

These metals are called "fixed charge metals"

the stairs:



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Naming Anions

Main group nonmetal anions (Groups VA, VIA, and VIIA) named by identifying the nonmetal and *changing ending to "ide"* followed by the word "ion":

Cl^-	Chloride ion
O^{2-}	Oxide ion
P^{3-}	Phosphide ion
C^{4-}	Carbide ion

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Naming Variable Charge Cations

Many metals (transition, lanthanide, actinide, etc.) can often form more than one type of cation. Use Roman number to describe charge on metal:

Cr^{2+}	Cr^{3+}
Chromium(II) ion	Chromium(III) ion

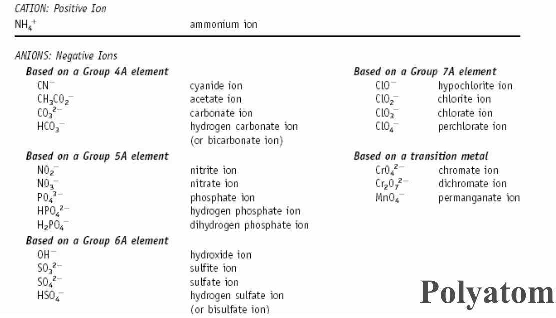
Roman numeral indicates charge on cation:

iron(III) would be Fe^{3+}

MAR

A *Polyatomic ion* is an ion composed of more than one atom. Formula for polyatomic ions shown by subscripts. *Example:* SO_4^{2-} ion has one sulfur atom, four oxygen atoms and a -2 charge

Many polyatomic ions known - *memorize*!



CATION: Positive Ion

NH_4^+ ammonium ion

ANIONS: Negative Ions

Based on a Group 4A element		***Based on a Group 7A element***	
CN^-	cyanide ion	ClO^-	hypochlorite ion
$CH_3CO_2^-$	acetate ion	ClO_2^-	chlorite ion
CO_3^{2-}	carbonate ion	ClO_3^-	chlorate ion
HCO_3^-	hydrogen carbonate ion (or bicarbonate ion)	ClO_4^-	perchlorate ion
Based on a Group 5A element		***Based on a transition metal***	
NO_2^-	nitrite ion	CrO_4^{2-}	chromate ion
NO_3^-	nitrate ion	$Cr_2O_7^{2-}$	dichromate ion
PO_4^{3-}	phosphate ion	MnO_4^-	permanganate ion
HPO_4^{2-}	hydrogen phosphate ion		
$H_2PO_4^-$	dihydrogen phosphate ion		
Based on a Group 6A element			
OH^-	hydroxide ion		
SO_3^{2-}	sulfite ion		
SO_4^{2-}	sulfate ion		
HSO_4^-	hydrogen sulfate ion (or bisulfate ion)		

Polyatomic Ions

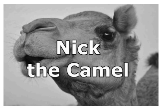
MAR

Introducing: Nick the Camel!

Nick *the* Camel Brat *ate* Icky Clam *for* Supper *in* Phoenix

MAR

Nick the Camel



Nick *the* Camel Brat *ate* Icky Clam *for* Supper *in* Phoenix

	Consonants = Oxygen	Vowels = Charge	Polyatomic Ion
Nick = Nitrate	3	-1	NO_3^-
Camel = Carbonate	3	-2	CO_3^{2-}
Brat = Bromate	3	-1	BrO_3^-
Icky = Iodate	3	-1	IO_3^-
Clam = Chlorate	3	-1	ClO_3^-
Supper = Sulfate	4	-2	SO_4^{2-}
Phoenix = Phosphate	4	-3	PO_4^{3-}
Did Nick have Crepes for dessert too? :)			
Crepes = chromate	4	-2	CrO_4^{2-}

MAR

Naming Ionic Compounds

Ionic compounds are named by citing first the cation and then the anion with a space between the words. For example:

$NaBr$ – Sodium bromide
$MgSO_4$ – Magnesium sulfate
$SnCl_2$ – Tin(II) chloride
$SnCl_4$ – Tin(IV) chloride
Al_2O_3 – Aluminum oxide

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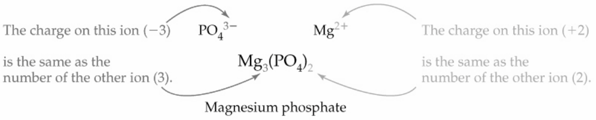
Formulas of Ionic Compounds

Formula of an ionic compound shows the *lowest possible ratio* of atoms in the compound.



The charge on this ion (−3) PO_4^{3-}

is the same as the number of the other ion (3).

Mg^{2+} The charge on this ion (+2)

is the same as the number of the other ion (2).

$Mg_3(PO_4)_2$

Magnesium phosphate

Practice, practice, practice!!!

MAR

Formulas of Ionic Compounds

$Na^+ + Cl^- = NaCl$
$Ca^{+2} + O^{-2} = CaO$
$Al^{+3} + S^{-2} = Al_2S_3$
$Li^+ + Br^- =$ $LiBr$
$Al^{+3} + I^- =$ AlI_3
$Sr^{+2} + P^{-3} =$ Sr_3P_2

$Ca^{+2} + Cl^- = CaCl_2$
$Na^+ + O^{-2} = Na_2O$
$Ca^{+2} + N^{-3} = Ca_3N_2$
$Mg^{+2} + F^- =$ MgF_2
$NH_4^+ + PO_4^{-3} =$ $(NH_4)_3PO_4$
Not $NH_{43}PO_4$
$K^+ + Cl^- =$ KCl

MAR

Make final compound neutral

Learning Check

Write the formulas and names for compounds of the following ions:

	Br^-	S^{2-}	N^{3-}
Na^+			
Al^{3+}			
Sn^{2+}			
Sn^{4+}			

Remember: To write formulas, cross the charge. To write the name, name the cation (Roman numeral if necessary) then the anion.

MAR

Learning Check - *Answers*

Write the formulas and names for compounds of the following ions:

	Br^-	S^{2-}	N^{3-}
Na^+	NaBr sodium bromide	Na_2S sodium sulfide	Na_3N sodium nitride
Al^{3+}	$AlBr_3$ aluminum bromide	Al_2S_3 aluminum sulfide	AlN aluminum nitride
Sn^{2+}	$SnBr_2$ tin(II) bromide	SnS tin(II) sulfide	Sn_3N_2 tin(II) nitride
Sn^{4+}	$SnBr_4$ tin(IV) bromide	SnS_2 tin(IV) sulfide	Sn_3N_4 tin(IV) nitride

MAR

Learning Check

Write formulas and names for compounds of the following ions.

	OH^-	CO_3^{2-}	PO_4^{3-}
NH_4^+			
Ca^{2+}			

Remember: To write formulas, cross the charges. To name an ionic compound, name the cation (with Roman numeral if necessary), then the anion. If you need more than one polyatomic ion, use parentheses with the number of ions as a subscript.

MAR

Learning Check - Answers

Write formulas and names for compounds of the following ions.

	OH^-	CO_3^{2-}	PO_4^{3-}
NH_4^+	NH_4OH ammonium hydroxide	$(NH_4)_2CO_3$ Ammonium carbonate	$(NH_4)_3PO_4$ ammonium phosphate
Ca^{2+}	$Ca(OH)_2$ Calcium hydroxide	$CaCO_3$ Calcium carbonate	$Ca_3(PO_4)_2$ calcium phosphate

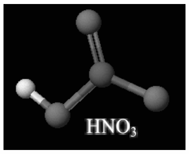
MAR

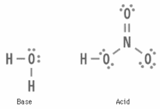
H^+ and Acids

The *Hydrogen cation* (H^+) contains only a proton (no electrons or neutrons).

Acids are substances that provide H^+ ions in water; for example, HCl, H_2SO_4, HNO_3.

HCl dissolved in water → H^+ + Cl^-





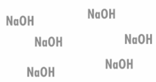
MAR

OH^- Ions and Bases

The *Hydroxide anion* (OH^-) is a polyatomic ion with a -1 charge.

Bases are substances that provide OH- ions in water; for example, NaOH, KOH, $Ba(OH)_2$.

NaOH dissolved in water → Na^+ + OH^-



MAR

Test Yourself: Ionic Compounds

Give the names for the following formulas:

$NaCl$
$CaBr_2$
MnF_2
$Ga_2(SO_4)_3$
$Cr(NO_3)_3$

Give the formulas for the following names:

hydrochloric acid
iron(III) oxide
potassium hydroxide
chromium(III) iodide

MAR *Practice, practice, practice!*

Covalent Bonds

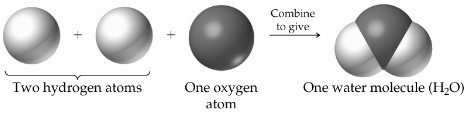
A ***covalent bond*** is a bond formed by sharing electrons between atoms.

A ***molecule*** is a group of atoms held together by covalent bonds.

Nonmetals form covalent bonds with nonmetals. They reach the Noble Gas configuration by *sharing* an appropriate number of electrons.

MAR

A water molecule results when two hydrogen atoms and one oxygen atom are covalently bonded:



MAR

Test Yourself

Are these compounds bonded through ionic or covalent bonding?

PCl_5
Na_2O
SO_3
$CaSO_3$
$SbAs$

Nomenclature of covalent compounds different from ionic compounds; important to know the difference

MAR

Naming Molecular Compounds

When two or more nonmetal elements combine they form *covalent compounds*.

The formulas of covalent compounds are written with the less electronegative (*i.e. more metal-like*) element first.

More electronegative element gets *-ide* suffix

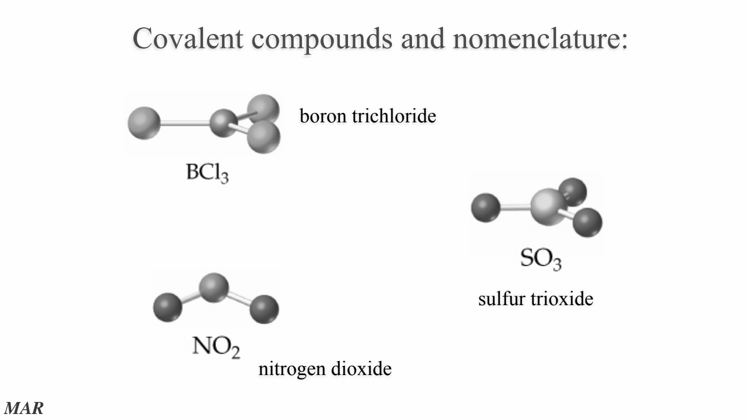
Use Greek Prefixes to indicate number of atoms present.

MAR

Greek Prefixes

1	***mono***	**6**	***hexa***
2	***di***	**7**	***hepta***
3	***tri***	**8**	***octa***
4	***tetra***	**9**	***nona***
5	***penta***	**10**	***deca***

MAR



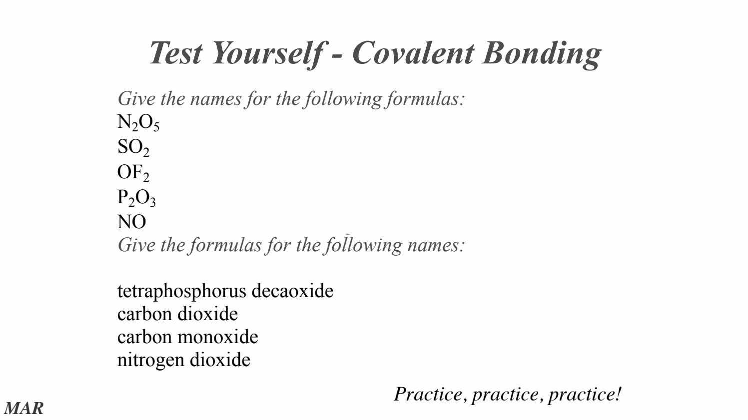
Covalent compounds and nomenclature:

BCl_3 boron trichloride

SO_3 sulfur trioxide

NO_2 nitrogen dioxide

MAR



Test Yourself - Covalent Bonding

Give the names for the following formulas:

N_2O_5

SO_2

OF_2

P_2O_3

NO

Give the formulas for the following names:

tetraphosphorus decaoxide

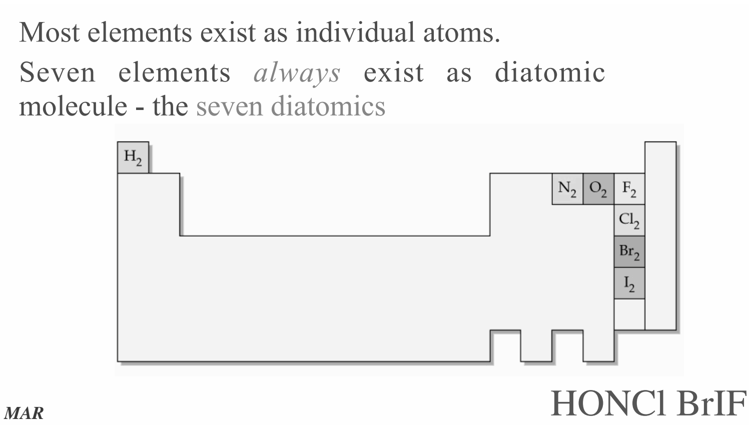
carbon dioxide

carbon monoxide

nitrogen dioxide

Practice, practice, practice!

MAR

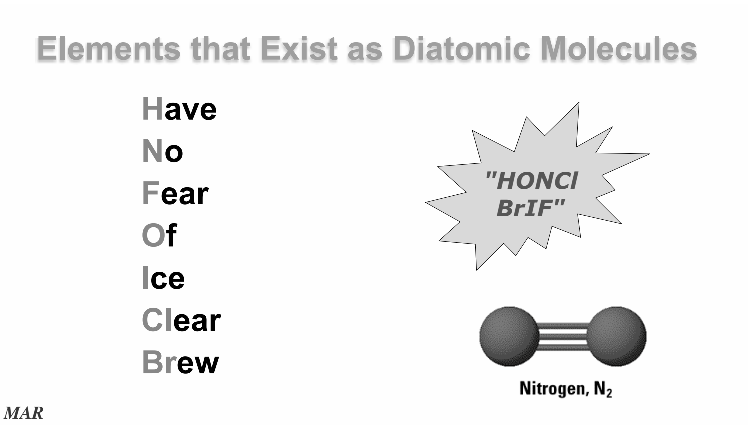


Most elements exist as individual atoms.

Seven elements *always* exist as diatomic molecule - the seven diatomics

HONCl BrIF

MAR



Elements that Exist as Diatomic Molecules

Have

No

Fear

Of

Ice

Clear

Brew

"HONCl BrIF"

Nitrogen, N_2

MAR

End of Chapter 4 (section 4.3)

Chemistry 151: Basic Chemistry

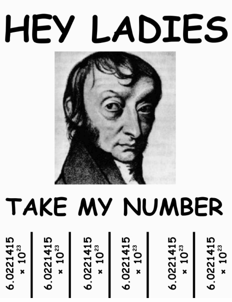
Chapter 2 Section 2.4: The Power of the Chemical Formula

Last update: 1/10/25

The Power of the Chemical Formula

A **chemical formula** provides a lot of information to the chemist.

We will explore the value of **molar mass**, **Avogadro's number** and **percent composition** in order to find the **empirical formula** and **molecular formula**.



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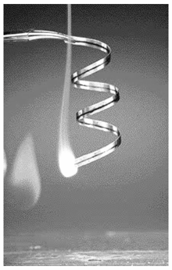
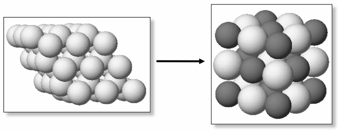
Counting Atoms



Mg burns in air (O_2) to produce white magnesium oxide, MgO.

How can we figure out how much oxide is produced from a given mass of Mg?



MAR

Counting Atoms

Chemistry is a quantitative science - we need a "counting unit."

The MOLE!

A mole is similar to a *dozen* - you can have a dozen roses, a dozen donuts - you can also have a mole of roses, or a mole of donuts

MAR

Particles in a Mole

Avogadro's Number (N_A), *named for* **Amedeo Avogadro,** *1776-1856*

$6.02214076 \times 10^{23}$

A mole is the amount of *any* substance containing 6.022×10^{23} particles

$$\frac{6.022 \times 10^{23} \text{ Cu atoms}}{1 \text{ mole Cu}} \qquad \frac{1 \text{ mole } CO_2}{6.022 \times 10^{23} \text{ molecules } CO_2}$$

MAR

How Big is a Mole?

If you distribute equally 6×10^{23} dollars to every human being on the planet and spend a million dollars an hour it would would take more than 10,000 years to spend your share!

Traveling at the speed of light it would take more than a 100 billion years to travel 6×10^{23} miles!

A stack of 6×10^{23} pennies would be so tall that it would take 100,000 years traveling at the speed of light to go from one end of the stack to the other!

It would take more than a 100 trillion years to print 6×10^{23} dollars at a rate of 100 dollars per second!

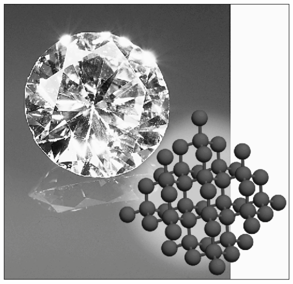
MAR

Molar Mass

1 mol of ^{12}C
= 12.00 g of C
= 6.022 x 10^{23} atoms of C

12.00 g of ^{12}C is its MOLAR MASS

Taking into account all of the isotopes of C, the molar mass of C is 12.011 g/mol



MAR

Molar Mass

1 mol of Al = 26.9815 g of Al
1 mol of Al = 6.022 x 10^{23} atoms of Al
26.9815 g of Al is its MOLAR MASS

We will write this as: **26.9815 g Al / 1 mol Al**

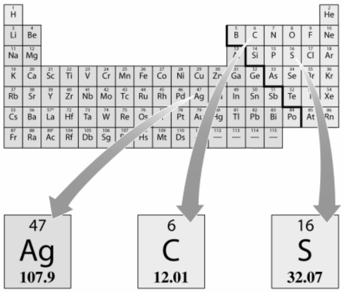
Find molar mass from periodic table

13 ← **atomic number**
Al ← **symbol**
26.9815 ← **atomic weight**

MAR

Molar Mass From the Periodic Table

Molar mass is the atomic weight expressed in grams per mol (g/mol), and these values come directly from the periodic table



1 mole Ag = 107.9 g

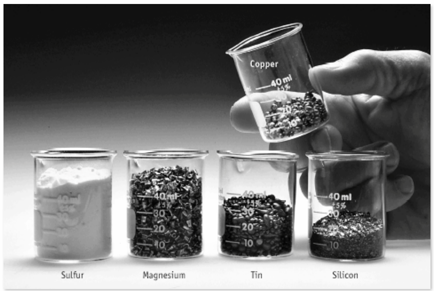
1 mole C = 12.01 g

1 mole S = 32.07 g

Molar mass of Ag = 107.9 g/mol

MAR

One mole Amounts



63.5 g Cu

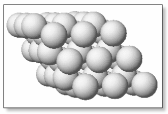
32.1 g S

24.3 g Mg

118.7 g Sn

28.1 g Si

MAR



PROBLEM: What amount of Mg is represented by 0.200 g? How many atoms?

Mg has a molar mass of 24.3050 g/mol.

$$0.200 \text{ g} \bullet \frac{1 \text{ mol}}{24.31 \text{ g}} = 8.23 \times 10^{-3} \text{ mol}$$

How many atoms in this piece of Mg?

$$8.23 \times 10^{-3} \text{ mol} \bullet \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}}$$

= 4.96 x 10^{21} atoms Mg

MAR

Atomic Weight

Atomic Weight: The weighted average mass of an element's atoms in a large sample that includes all naturally occurring isotopes of that atom.

Atomic number and atomic weight displayed in periodic table

Atomic weight (amu) and **molar mass** (g/mol): *same number, different units!*

* *Atomic weight for* ***one*** *atom*

* *Molar mass for grams in a mole (**6.022x10^{23} atoms**)*

13 ← **atomic number**
Al ← **symbol**
26.9815 ← **atomic weight**

MAR

Molecular weight: The sum of atomic weights for all atoms in a molecule

Example (use a periodic table):

- **Carbon**: **12.01 amu** *(the **atomic weight**)*
- **Oxygen**: **16.00 amu** *(the **atomic weight**)*
- **Carbon monoxide (CO)**: **28.01 amu** = 12.01 + 16.00 *(28.01 is the **molecular weight** for CO)*
- 28.01 *is also the* molar mass *of CO (in* g/mol*) - the mass in grams of* $6.022x10^{23}$ *molecules of CO)*

Molecular weight and molar mass: same number, different units (and uses)

Molecular Weight

MAR

Molar Mass

Example: Find the molar mass of H_2O.

Water has 2 H and 1 O

2*H = 2*1.008 = 2.016 *grams*

1*O = 1*15.999 = 15.999 *grams*

so: Molar mass =

15.999 + 2.016 = **18.015** ***grams per mole***

This means that in 18.015 grams of water we have one mole of molecules of water

One mole of water molecules equals $6.022*10^{23}$ molecules of water

MAR

We can convert mol of water to g and g of water to mol using "18.0 g / mol" and dimensional analysis:

Molar mass used as conversion factor

$$0.25\ \cancel{\text{mol } H_2O} \times \frac{18.0\ \text{g } H_2O}{1\ \cancel{\text{mol } H_2O}} = 4.5\ \text{g } H_2O$$

Molar mass used as conversion factor

$$27\ \cancel{\text{g } H_2O} \times \frac{1\ \text{mol } H_2O}{18.0\ \cancel{\text{g } H_2O}} = 1.5\ \text{mol } H_2O$$

MAR

Molar Mass

What is the molar mass of Urea, $(NH_2)_2CO$?

Solution:

2 x N = 2 x 14.0067 = 28.0134

1 x C = 1 x 12.0111 = 12.0111

4 x H = 4 x 1.00794 = 4.03176

1 x O = 1 x 15.9994 = 15.9994

TOTAL = 60.0556 g/mol

MAR

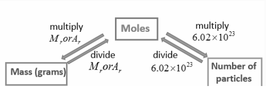
Test Yourself Part 1

What is the molar mass of potassium dichromate, $K_2Cr_2O_7$?

MAR

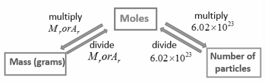
Test Yourself Part 2

How many moles in 35.013 g of $K_2Cr_2O_7$?



MAR

Test Yourself Part 3



How many molecules of $K_2Cr_2O_7$ in 35.013 g?

MAR

Percent Composition

Chemists wish to determine the elements present in a compound and their **percent by mass**.

- Percent by mass also known as "percent by weight"

Example: A 100g sample of a new compound contains 55 g of element X and 45 g of element Y

Percent by mass can be calculated using:

$$\frac{\textit{Mass of element}}{\textit{Mass of compound}} \; X\ 100 = \textbf{percent by mass}$$

55% X and 45% Y

Percents of all elements in compound must equal 100%

MAR

Percent Composition from the Chemical Formula

If you know the chemical formula for a compound, you can calculate its percent composition:

1. Calculate the molar mass of each element in the compound formula unit
   a. Assume sample size is one mole
   b. Multiply the molar mass of the element by its subscript in the chemical formula
2. Divide the mass of the element by the molar mass of the compound unit and multiply by 100

MAR

Percent Composition from the Chemical Formula

Example: Find the percent composition of water, H_2O

- Hydrogen – 1.01 x 2 = 2.02 g H in water
  Oxygen – 16.00 x 1 = 16.00 g O in water
  Molar mass = 2.02 + 16.00 = 18.02 g/mol of H_2O

- % of H: $\frac{2.02 \text{ g H}}{18.02 \text{ g } H_2O}$ x 100% = **11.2 %H in Water**
  % of O: $\frac{16.00 \text{ g O}}{18.02 \text{ g } H_2O}$ x 100% = **88.79 %O in Water**

Water is 11.2% H and 88.79% O

Check: 11.2 + 88.8 = 99.99% :)

MAR

Percent Composition from the Chemical Formula

Determine the percent composition of Sodium Hydrogen Carbonate ($NaHCO_3$)

First find molar mass (g/mol)

Na = 1* 22.99 g = 22.99 g Na

H = 1* 1.01 g = 1.01 g H

C = 1* 12.01 g = 12.01 g C

O = 3* 16.00 g = <u>48.00 g O</u>

84.01 g/mol $NaHCO_3$

MAR

Percent Composition from the Chemical Formula

Sodium: $\frac{22.99 \text{ g Na}}{84.01 \text{ g } NaHCO_3}$ x 100% = **27.37 % Na**

Hydrogen: $\frac{1.01 \text{ g H}}{84.01 \text{ g } NaHCO_3}$ x 100% = **1.20 % H**

Carbon: $\frac{12.01 \text{ g C}}{84.01 \text{ g } NaHCO_3}$ x 100% = **14.30 % C**

Oxygen: $\frac{48.00 \text{ g O}}{84.01 \text{ g } NaHCO_3}$ x 100% = **57.14 % O**

check: 27.37% + 1.20% + 14.30% + 57.14% = 100.01%

MAR

Empirical Formula (EF) and Molecular Formula (MF)

Finding the molecular formula (MF) is a "holy grail" for chemists. If they can determine the MF, they know what the compound is, etc.

To find the MF, chemists first have to find the empirical formula (EF), then compare the EF to the molar mass.

MAR

Empirical Formula (EF) and Molecular Formula (MF)

Molecular formula: the true number of atoms of each element in the formula of a compound.

Empirical formula: the lowest whole number ratio of atoms in a compound.

molecular formula = (empirical formula)$_n$

molecular formula = C_6H_6 = $(CH)_6$

empirical formula = CH

MAR

Empirical Formula (EF) and Molecular Formula (MF)

Formulas for ionic compounds are **ALWAYS** empirical (lowest whole number ratio).

Examples:

NaCl	$Al_2(SO_4)_3$
$MgCl_2$	K_2CO_3

MAR

Empirical Formula (EF) and Molecular Formula (MF)

Formulas for molecular compounds *MIGHT* be empirical (lowest whole number ratio).

Molecular:	H_2O	$C_6H_{12}O_6$	$C_{12}H_{22}O_{11}$
	↓	↓	↓
Empirical:	H_2O	CH_2O	$C_{12}H_{22}O_{11}$

MAR

Empirical Formula (EF) and Molecular Formula (MF)

Molecular Formula	Empirical Formula
N_2O	N_2O
$C_2H_4O_2$	CH_2O
$C_2H_6O_2$	CH_3O
N_2O_4	NO_2

Notice:

1. The molecular formula and the empirical formula *can* be identical
2. You scale up from the empirical formula to the molecular formula by a whole number factor

MAR

Empirical Formula via Mass Percentages

To find the Empirical Formula from mass percentages:

1. Assume 100 grams of the substance and convert % into grams.
2. Convert grams to moles by dividing the amount in grams by the molar mass of that element.
3. Select the SMALLEST mole value and divide ALL mole values by this smallest one.
4. The results of Step 3 will either be VERY close to whole numbers or will be recognizable mixed number fractions If any result from Step 3 is a decimal mixed number, you must multiply ALL values by some number to make it a whole number. Ex: 1.33 x 3, 2.25 x 4, 2.50 x 2, etc.

MAR

Let's see some examples

Empirical Formula via Mass Percentages

Example: The percent composition of a sulfur oxide is 40.05 % S and 59.95 % O. Find the empirical formula.

Step 1: Convert % to grams (assume 100 g), then find moles of each element

$$\frac{40.05 \text{ g S}}{32.07 \text{ g/mol S}} = 1.249 \text{ mol S}$$

$$\frac{59.95 \text{ g O}}{16.00 \text{ g/mol O}} = 3.747 \text{ mol O}$$

MAR

Empirical Formula via Mass Percentages

Example: The percent composition of a sulfur oxide is 40.05 % S and 59.95 % O. Find the empirical formula.

Step 2: Divide the mole values by the value of the element with the *smallest* number of moles (sulfur).

$$\frac{1.249 \text{ mol S}}{1.249} = 1 \text{ mol S}$$

$$\frac{3.747 \text{ mol O}}{1.249} = 3 \text{ mol O}$$

Empirical Formula = SO_3

MAR

Empirical Formula via Mass Percentages

In this example, the simplest whole number mole ratio of S atoms to O atoms is 1:3. The empirical formula for the oxide of sulfur is **SO_3**

Note that the calculated mole values may not always be whole numbers.

In these cases all the mole values must be multiplied by the smallest factor that will make them whole numbers

MAR

Practice Problem

Butene is hydrocarbon, a compound composed only of carbon and hydrogen. It is 85.63% carbon and 14.37% hydrogen. What is the empirical formula?

Assume 100 g total.

85.63 g C * (mol C / 12.01 g C) = 7.130 mol C

14.37 g H * (mol C / 1.008 g H) = 14.26 mol H

14.26 / 7.130 = 2.000 mol H

7.130 / 7.130 = 1.000 mol C

Empirical Formula = CH_2

MAR

Molecular Formulas

Two or more substances with distinctly different properties can have the same percent composition and the same empirical formula

Example: NO_2 and N_2O_4: same EF, different compounds

Example: C_2H_4 and C_4H_8: same EF, different compounds

Empirical formulas do not always indicate the actual moles in the compound! Chemists need a molecular formula to fully describe a compound.

MAR

Determining Molecular Formulas

A molecular formula specifies the actual number of atoms of each element in one molecule or formula unit of the substance

The **molar mass** must be determined through a separate experiment *(mass spectrometer)* and compared with the empirical formula to find the molecular formula.

Let's see an example!

MAR

Determining Molecular Formulas

Example: The molar mass of a compound is 181.50 g/mol and the empirical formula is C_2HCl. What is the molecular formula?

First, find molar mass of empirical formula (C_2HCl):
2*C + 1*H + 1*Cl = 2*12.01 + 1*1.01 + 1*35.45
= 60.48 g/mol for C_2HCl

Now compare molar mass of compound (181.50) to molar mass of EF (60.48) - should always get a whole number!
181.50 / 60.48 = 3.001 which is essentially 3

Multiply this ratio by the EF to get the MF:

Molecular Formula = $(C_2HCl)_3$ = $C_6H_3Cl_3$

MAR

Test Yourself!

Analysis of a weak acid finds a chemical composition of 49.32 %C, 6.85 %H, and 43.84 %O. The molar mass is 146 g/mol. Determine the empirical and molecular formulas.

Steps:

- assume 100 g, so %s equal g of the element
- turn g of element into moles
- divide moles by smallest number to find EF
- turn EF into a molar mass
- compare molar mass of compound (146) to EF molar mass to find ratio, then MF

MAR

Test Yourself!

Analysis of a weak acid finds a chemical composition of 49.32 %C, 6.85 %H, and 43.84 %O. The molar mass is 146 g/mol. Determine the empirical and molecular formulas.

49.32 %C = 49.32 g of C, etc. *Turn to moles:*
49.32 g C * (mol C / 12.01 g C) = 4.107 mol C
6.85 g H * (mol H / 1.01 g H) = 6.78 mol H
43.84 g O * (mol C / 16.00 g O) = 2.740 mol O

2.740 is smallest, so find EF:
C(4.107/2.740) H(6.78/2.740) O(2.740/2.740)
C(1.499) H(2.47) O(1.000) ≈ $C_{1.5}\ H_{2.5}\ O_1$

Multiply by 2 to eliminate fraction:
$(C_{1.5}\ H_{2.5}\ O_1)_2$ = $C_3H_5O_2$ = *Empirical Formula*

MAR

Test Yourself!

Analysis of a weak acid finds a chemical composition of 49.32 %C, 6.85 %H, and 43.84 %O. The molar mass is 146 g/mol. Determine the empirical and molecular formulas. (EF = $C_3H_5O_2$ via previous page)

To find MF, *find molar mass of EF ($C_3H_5O_2$) and compare to 146 g/mol:*
(3C*12.01 g/mol) + (5H*1.01 g/mol) + (2O*16.00 g/mol) = 73.07 g/mol *(molar mass of EF)*
146 / 73.07 = 2.00 *ratio should always be whole number*

$(C_3H_5O_2)_2$ = $C_6H_{10}O_4$ = **molecular formula (MF)**

This is adipic acid!

MAR

Test Yourself!

A colorless liquid composed of 46.68% nitrogen and 53.32% oxygen has a molar mass of 60.01 g/mol. What is the molecular formula?

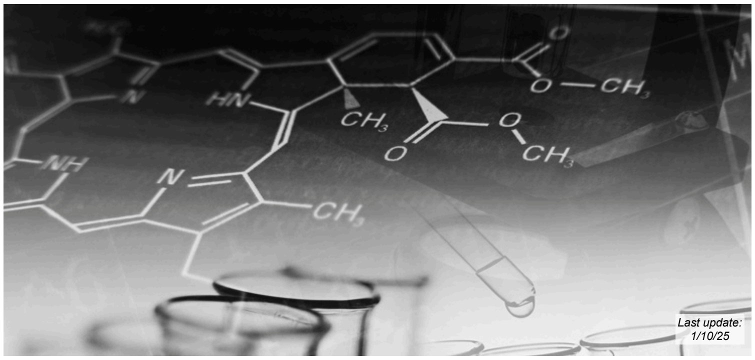
Answers: EF = NO, MF = N_2O_2

MAR

End of Chapter 2 Section 2.4

Chemistry 151: Basic Chemistry

Chapter 7 Section 7.1: The Chemical Reaction



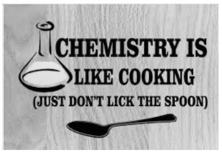
Last update: 1/10/25

Chemical Equations

Chemical equations are like recipes in cooking: They tell a chemist how to make something ("products") and what you'll need to make it ("reactants")

Having balanced amounts critical in cooking: too much flour can make a cake dry, and too little flour can prevent the cake from forming. Same in chemistry!

We will learn how to create a balanced chemical equation in this chapter, and in the next section, we will explore the quantities needed to actually make the products.



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Chemical Equations

Chemical equation: An expression in which symbols and formulas are used to represent a chemical reaction.

Reactant: A substance that undergoes change in a chemical reaction; written on *left side* of the reaction arrow

Product: A substance that is formed in a chemical reaction; written on *right side* of reaction arrow

$$2\,\underbrace{NaHCO_3}_{\text{Reactant}} \xrightarrow{\text{Heat}} \underbrace{Na_2CO_3 + H_2O + CO_2}_{\text{Products}}$$

MAR

Chemical Equations

Equations depict the *kind* of reactants and products and their relative amounts in a reaction.

$$4\ \mathbf{Al(s)} + 3\ \mathbf{O_2(g)} \dashrightarrow 2\ \mathbf{Al_2O_3(s)}$$

The numbers in the front are called

stoichiometric coefficients

The letters (s), (g), (l) and (aq) are the physical states of compounds:

s = solid, g = gas, l = liquid,

aq = solution in water (aqueous)

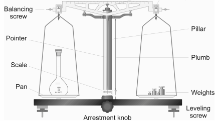
MAR

The ***Law of conservation of mass*** states that matter cannot be created or destroyed in any chemical reaction

The bonds between atoms in the reactants are rearranged to form new compounds, but none of the atoms disappear, and no new atoms are formed.

So: Chemical equations must be *balanced*, meaning the numbers and kinds of atoms must be the same on both sides of the reaction arrow.

The numbers placed in front of formulas to balance equations are called *coefficients*, and they multiply all the atoms in the chemical formula.



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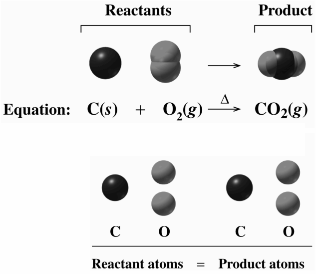
Chemical Equations are Balanced

In a **balanced chemical reaction:**

- atoms are not gained or lost.
- the number of reactant atoms is equal to the number of product atoms.



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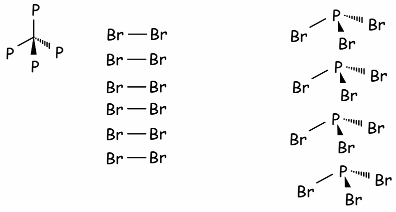
$P_4 + 6\ Br_2 \longrightarrow 4\ PBr_3$



Balance Sheet:

$4\,P + 12\ Br \longrightarrow 4\,P + 12\ Br$

MAR

Balancing Chemical Equations

The following four steps can be used as a guide to balance chemical equations.

Example: Sulfuric acid reacts with sodium hydroxide to create sodium sulfate and water. Balance this chemical reaction.

Step 1: Write an unbalanced equation, using correct formulas for all reactants and products.

$H_2SO_4 + NaOH \longrightarrow Na_2SO_4 + H_2O$ (Unbalanced)

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Step 2: Add appropriate coefficients to balance the numbers of atoms of each element.

$H_2SO_4 + 2\,NaOH \longrightarrow Na_2SO_4 + H_2O$ (Balanced for Na)

Add this coefficient . . . . . . to balance these 2 Na.

$H_2SO_4 + 2\,NaOH \longrightarrow Na_2SO_4 + H_2O$ (Balanced for Na and sulfate)

One sulfate here . . . . . . and one here.

Step 3: Check the equation to make sure the numbers and kinds of atoms on both sides of the equation are same.

$H_2SO_4 + 2\,NaOH \longrightarrow Na_2SO_4 + 2\,H_2O$ (Completely balanced)

4 H and 2 O here. 4 H and 2 O here.

Step 4: Make sure the coefficients are reduced to their lowest whole-number value (ok here).

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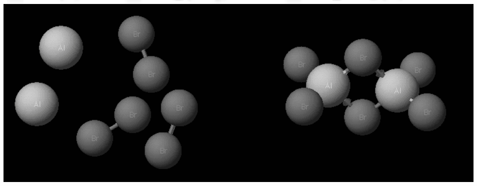
Balancing Equations

_ $Al(s)$ + _ $Br_2(liq)$ ---> _ $Al_2Br_6(s)$



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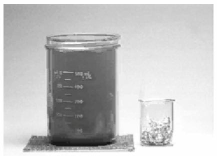
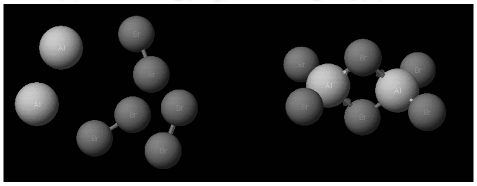


Balancing Equations

2 $Al(s)$ + 3 $Br_2(liq)$ ---> $Al_2Br_6(s)$



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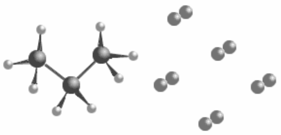

Balancing Equations

____ $C_3H_8(g)$ + _____ $O_2(g)$ -->

_____ $CO_2(g)$ + _____ $H_2O(g)$

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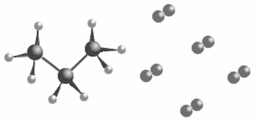

Balancing Equations

$C_3H_8(g)$ + 5 $O_2(g)$ ---->
3 $CO_2(g)$ + 4 $H_2O(g)$

MAR

Balancing Equations

Balance the following:
Calcium + nitrogen → Calcium nitride

MAR

Balancing with Polyatomic Ions

Magnesium chloride + sodium phosphate →
magnesium phosphate + sodium chloride

$MgCl_2(aq) + Na_3PO_4(aq) \rightarrow NaCl(aq) + Mg_3(PO_4)_2(s)$

Leave polyatomic ions as "units", don't break up when balancing, usually balance them first before other atoms

$MgCl_2(aq) + 2Na_3PO_4(aq) \rightarrow NaCl(aq) + Mg_3(PO_4)_2(s)$

$3MgCl_2(aq) + 2Na_3PO_4(aq) \rightarrow 6NaCl(aq) + Mg_3(PO_4)_2(s)$

2 PO_4^{3-} = 2 PO_4^{3-}
3 Mg^{2+} = 3 Mg^{2+}
6 Na^+ = 6 Na^+
6 Cl^- = 6 Cl^-

Balanced!

MAR

Balancing Equations

Balance the following. To save time, balance polyatomic ions as units (not individual atoms):

$BaCl_2 + Na_3PO_4 \rightarrow Ba_3(PO_4)_2 + NaCl$

MAR

Balancing Equations - Hints

- Balance those atoms which occur in only one compound on each side
- Balance the remaining atoms
- Reduce coefficients to smallest whole integers
- Check your answer
- *Remember the seven diatomics! HONCl BrIF*

MAR

Test Yourself

Balance the following reactions:

$K_{(s)} + H_2O_{(l)} \rightarrow H_{2(g)} + KOH_{(aq)}$

$Ba_{(s)} + H_3AsO_{4(aq)} \rightarrow H_{2(g)} + Ba_3(AsO_4)_{2(aq)}$

$PCl_{5(s)} + H_2O_{(l)} \rightarrow H_3PO_{4(aq)} + HCl_{(aq)}$

$KClO_{3(s)} \rightarrow KCl_{(s)} + O_{2(g)}$

MAR

practice, practice, practice!

Types of Reactions

Most chemical reactions can be grouped into one of these six categories:

1. **Combination** A + B → AB
2. **Decomposition** AB → A + B
3. **Single Replacement** AB + C → CB + A *or* MY + X → MX + Y

(Metals replace metals; nonmetals replace nonmetals)

4. **Combustion** $C_xH_y + O_2 \rightarrow CO_2 + H_2O$
5. **Acid-Base** $HX + MOH \rightarrow MX + H_2O$
6. **Precipitation** $AX + BY \rightarrow AY(s) + BX$

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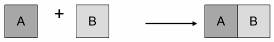
Combination (Addition)

In a **combination reaction**, two or more reactants form one product or simple compounds combine to form one product.



$2\ Mg(s) + O_2(g) \longrightarrow 2\ MgO(s)$

$2\ Na(s) + Cl_2(g) \longrightarrow 2\ NaCl(s)$

$SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(aq)$

Combination reactions are also known as **addition reactions.**

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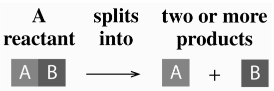
Decomposition

In a **decomposition reaction**, one substance splits into two or more simpler substances.



$2\ HgO(s) \longrightarrow 2\ Hg(l) + O_2(g)$

$2\ KClO_3(s) \longrightarrow 2\ KCl(s) + 3\ O_2(g)$

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Learning Check

Classify the following reactions as combination or decomposition.

$H_2(g) + Br_2(g) \longrightarrow 2\ HBr(l)$ *Combination*

$Al_2(CO_3)_3(s) \longrightarrow Al_2O_3(s) + 3\ CO_2(g)$ *Decomposition*

$4\ Al(s) + 3\ C(s) \longrightarrow Al_4C_3(s)$ *Combination*

MAR

Single Replacement Reactions

Single replacement reactions:

$$A + BC \rightarrow AC + B$$
$$X + BY \rightarrow BX + Y$$

Metal (A and B) replace metals;

Non-metals (X and Y) replace non-metals

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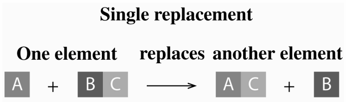
Single Replacement

In a **single replacement** reaction, one element takes the place of a different element in a reacting compound.



Metals (Zn and Ag) replacing metals:

$Zn(s) + 2\ AgCl(aq) \longrightarrow ZnCl_2(aq) + 2\ Ag(s)$

Nonmetals (Br and Cl) replacing nonmetals:

$Br_2(g) + 2\ NaCl(aq) \longrightarrow 2\ NaBr(aq) + Cl_2(g)$

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Learning Check

Complete and balance the following single replacement equation:

Metals replace metals:

zinc + silver nitrate →

Non-metals replace non-metals:

chlorine + sodium iodide →

MAR

Combustion Reactions

In a combustion reaction, a hydrocarbon (containing C, H and/or O) reacts with oxygen (O_2) to make carbon dioxide and water. These are very common in organic chemistry (and in your combustion gasoline car!)

$$C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ H_2O(g) + 2\ CO_2(g)$$

$$C_6H_{12}(g) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(g)$$

$$2\ C_2H_4O(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 4\ H_2O(g)$$

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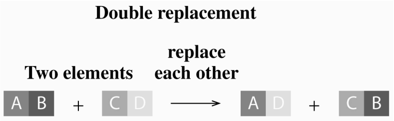
Acid-Base Reactions

In an acid-base reaction, an acid (H listed first) reacts with a base (metal hydroxide) to create water and a "salt"



$HNO_3(aq)$ + $NaOH(aq)$ ⟶ $H_2O(l)$ + $NaNO_3(aq)$

acid *base* *water* *salt*

Acid-Base reactions are also a type of **double displacement** or **exchange reactions**

MAR

Acid-Base Reactions

When equal amounts (moles) of acids (H^+) and bases (OH^-) are mixed together, both acidic and basic properties disappear because of a neutralization reaction. The neutralization reaction produces water and a salt.

Example: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

acid *base* *water* *salt*

MAR

Acid-Base Reactions

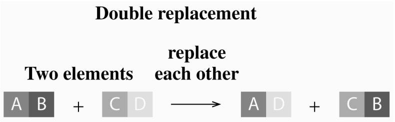
Example: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

acid *base* *water* *salt*

MAR

Precipitation Reactions

In a precipitation reaction, reactants exchange cations, and at least one of the products is a solid (a *precipitate*)



$AgNO_3(aq)$ + $NaCl(aq)$ ⟶ $AgCl(s)$ + $NaNO_3(aq)$

precipitate

Precipitation reactions are also a type of **double displacement** or **exchange reactions**

MAR

Precipitation Reactions

Solubility: The amount of a compound that will dissolve in a given amount of solvent at a given temperature.

When solubility exceeded, precipitates form

$Pb(NO_3)_2(aq) + 2\ KI(aq) \rightarrow PbI_2(s) + 2\ KNO_3(aq)$

MAR

Test Yourself

Balance and classify the following reactions:

$C_5H_{12}(l) + O_2(g) \rightarrow$

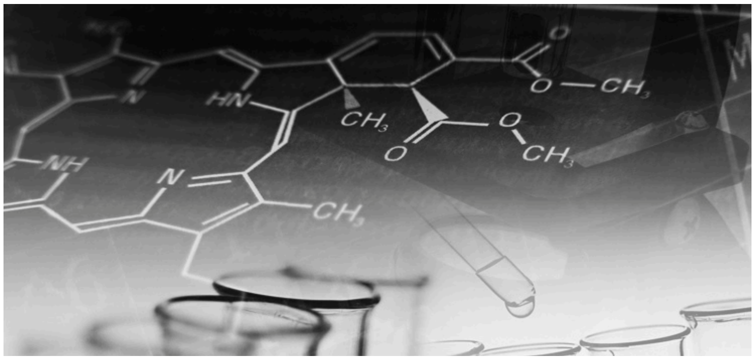
$HCl(aq) + Pb(NO_3)_2(aq) \rightarrow$ *$PbCl_2(s)$ is a product*

$HI(aq) + LiOH(aq) \rightarrow$

practice, practice, practice!

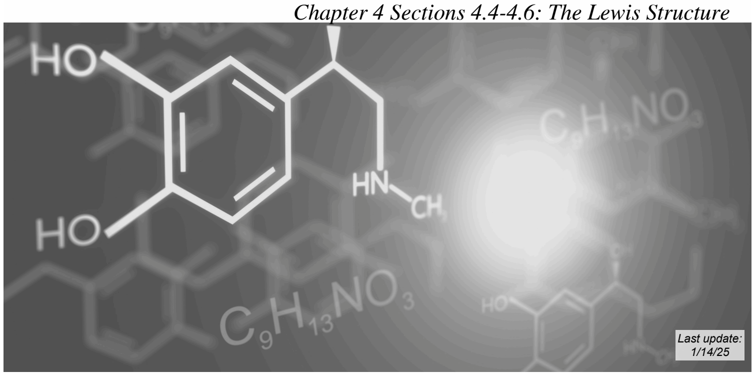
MAR

End of Chapter 7 Section 7.1



Chemistry 151: Basic Chemistry

Chapter 4 Sections 4.4-4.6: The Lewis Structure



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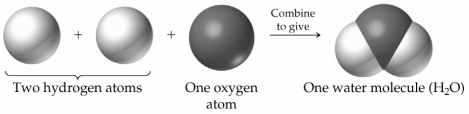
Covalent Bonds

A ***covalent bond*** is a bond formed by sharing electrons between atoms.

A ***molecule*** is a group of atoms held together by covalent bonds.

Nonmetals form covalent bonds with nonmetals. They reach the Noble Gas configuration by *sharing* an appropriate number of electrons.

A water molecule results when two hydrogen atoms and one oxygen atom are covalently bonded:



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Test Yourself

Are these compounds bonded through ionic or covalent bonding?

PCl_5
Na_2O
SO_3
$CaSO_3$
SbAs

Nomenclature *of covalent compounds different from ionic compounds; important to know the difference*
ex: Na_2O = sodium oxide, CO_2 = carbon dioxide

MAR

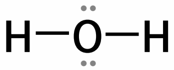
Covalent Bonds and the Periodic Table

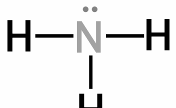
Covalent bonds can form between nonmetals, making possible a vast number of molecular compounds.

Water, H_2O, consists of two hydrogen atoms joined by covalent bonds to one oxygen atom with two lone pairs on oxygen

Ammonia, NH_3, consists of three hydrogen atoms joined by covalent bonds to one nitrogen atom with one lone pair on nitrogen

In most covalent molecules, each atom shares enough electrons to achieve a noble gas configuration.





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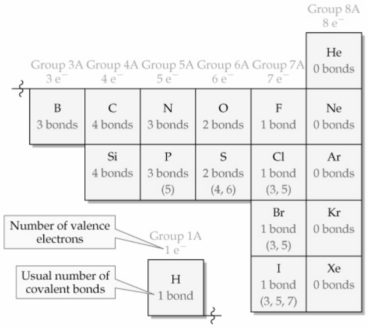

Note that **number of valence electrons equals the group number** for the element!

Note: For P, S, Cl, and other elements in the third period and below, the number of covalent bonds may vary, as indicated by the numbers shown in parentheses.

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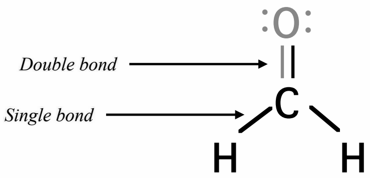
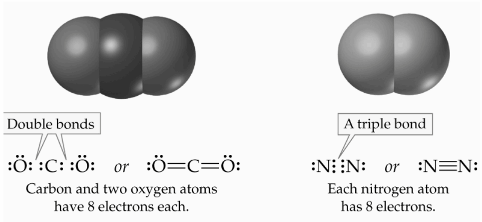
Multiple Covalent Bonds

Single bond: A bond formed by sharing two electrons or one pair – represented by a single line between the atoms.

Double bond: A bond formed by sharing four electrons or two pairs – represented by two lines (=) between the atoms.



Triple bond: A bond formed by sharing six electrons or three pairs– represented by three lines (≡) between the atoms.



Carbon and two oxygen atoms have 8 electrons each.

Each nitrogen atom has 8 electrons.

Molecular Formulas and Lewis Structures

Molecular Formula: A formula that shows the number and kind of atoms in a molecule

Structural formula: Molecular representation that shows the connections among atoms by using lines to represent covalent bonds

Example for water:

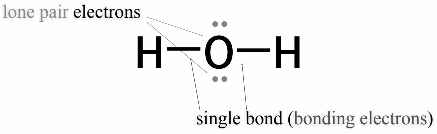
H_2O = molecular formula

H-O-H = structural formula

Lewis structure: Molecular representation showing both the connections among atoms *and* the locations of lone pair valence electrons.

A ***lone pair*** is a pair of electrons not used for bonding.

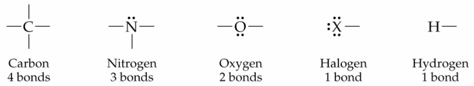
Lewis structure example for water:



Drawing Lewis Structure

To draw a Lewis structure, you need to know the connections among atoms.

Knowing *common bonding patterns* simplifies writing Lewis structure.



Building a Lewis Dot Structure

Ammonia, NH_3

1. Count valence electrons

H = 1 and N = 5

Total = (3 x 1) + 5

= 8 electrons *or*

4 pairs of electrons

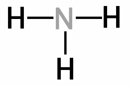
2. Decide on the central atom; never H.

Central atom is atom of lowest affinity for electrons.

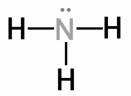
Therefore, N is central

Building a Lewis Dot Structure

3. **Form a sigma bond *(single bond)* between the central atom and surrounding atoms.**



4. **Remaining electrons form LONE PAIRS to complete octet as needed.**



3 BOND PAIRS and 1 LONE PAIR. *Note that N has a share in 4 pairs (8 electrons), while H shares 1 pair.*

Unshared electron pairs ("lone pairs") take up more volume than shared electron pairs ("bonding pairs")

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Lewis structure rules:

1: Decide on a central atom (usually listed first in formula, never H) and find the total number of valence electrons in molecule or ion

2: Draw a line between each pair of connected atoms to represent a covalent bond

3: Add lone pairs so that each *peripheral* atom (except H) gets an octet

4: Place all remaining electrons on the central atom

5: If central atom does not have an octet, take lone pair(s) from neighboring atom(s) and form multiple bond(s) to the central atom

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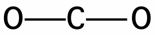
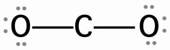
Carbon Dioxide, CO_2

1. **Central atom = _______**
2. **Valence electrons = __ or __ pairs**
3. **Form sigma bonds.**



This leaves 6 pairs.

4. **Place lone pairs on outer atoms.**



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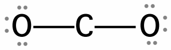
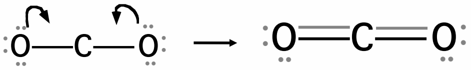
Carbon Dioxide, CO_2

4. **Place lone pairs on outer atoms.**



5. **So that C has an octet, we shall form DOUBLE BONDS between C and O.**



The second bonding pair forms a pi (π) bond.

This is the Lewis structure for CO_2

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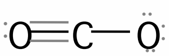
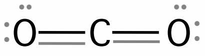
Resonance Structures of CO_2

Could have written CO_2 with a triple bond instead of two double bonds:



or



Energetically similar, they are called resonance structures of CO_2.

Provides additional stability to the molecule.

Practice, practice, practice!

MAR

Shape of Molecules

Molecular shapes can be predicted by noting how many bonds and electron pairs surround individual atoms and applying ***valence-shell electron-pair repulsion*** *(VSEPR)* theory.

Basic idea of VSEPR: negatively charged electron clouds in bonds and lone pairs repel each other, keeping them as far apart as possible

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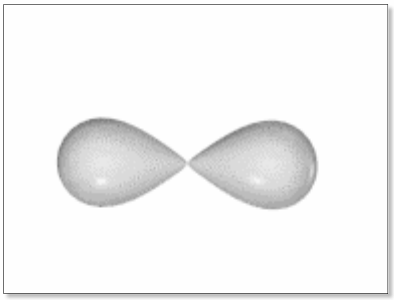
VSEPR



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VSEPR Rules

To apply VSEPR theory:

1: Draw the Lewis structure of the molecule and identify the central atom

2: Count the number of electron charge clouds (lone *and* bonding pairs) surrounding the central atom.

3: Predict molecular shape by assuming that clouds orient so they are as far away from one another as possible.

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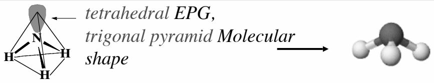
VSEPR Shape Predictor Table

Clouds	Bonds	Lone Pairs	Electron Pair Geometry (EPG)	Molecular Geometry (MG)	Angles	Notes
2	2	0	linear	linear	180	
3	3	0	trigonal planar	trigonal planar	120	
3	2	1	trigonal planar	bent	120	*always polar*
4	4	0	tetrahedral	tetrahedral	109	
4	3	1	tetrahedral	trigonal pyramid	109	*always polar*
4	2	2	tetrahedral	bent	109	*always polar*



tetrahedral EPG,
trigonal pyramid Molecular
shape

MAR

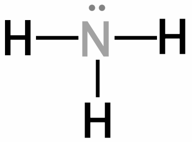
Structure Determination by VSEPR

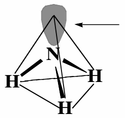
Ammonia, NH_3

1. Draw electron dot structure

2. Count BPs and LPs = 4

3. The 4 electron pairs are at the corners of a tetrahedron.





lone pair of electrons in tetrahedral position

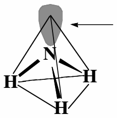
The ELECTRON PAIR GEOMETRY is tetrahedral.

MAR

Structure Determination by VSEPR

Ammonia, NH_3

The electron pair geometry is tetrahedral.



lone pair of electrons in tetrahedral position

The MOLECULAR GEOMETRY - the positions of the atoms - is TRIGONAL PYRAMID

MAR

Test Yourself

Describe the Lewis structure, electron pair geometry and molecular shape of methane, CH_4.

MAR

Polar Covalent Bonds and Electronegativity

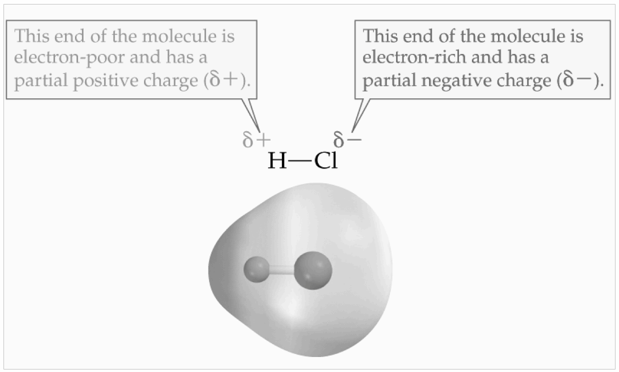
Electrons in a covalent bond occupy the region between the bonded atoms.

If atoms in bond identical (H_2, Cl_2, etc.) electrons are attracted equally to both atoms and are shared equally (**nonpolar**)

If atoms in bond different (HCl, HF, etc.) electrons may be attracted more strongly by one atom than by the other and are shared unequally.

Such bonds are known as **polar *covalent bonds.*** *Most bonds are polar!*

MAR



This end of the molecule is electron-poor and has a partial positive charge (δ+).

This end of the molecule is electron-rich and has a partial negative charge (δ−).

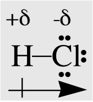
MAR

In HCl, electrons spend more time near Cl than H. Although molecule is overall neutral, the chlorine is more negative than the hydrogen, resulting in partial charges on the atoms.

Partial charges represented by placing δ- on the more negative atom and δ+ on the more positive atom.

Ability of an atom to attract electrons is called the atom's ***electronegativity***.

Fluorine, the most electronegative element, assigned a value of 4, and less electronegative atoms assigned lower values



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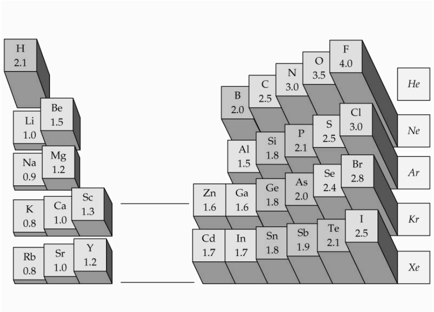

Electronegativities and the periodic table

MAR

Polar Molecules

Entire molecule can be polar *if* electrons are attracted more strongly to one part of the molecule than another.

Molecule's polarity is due to the sum of all individual bond polarities *and* lone-pair contributions in the molecule.

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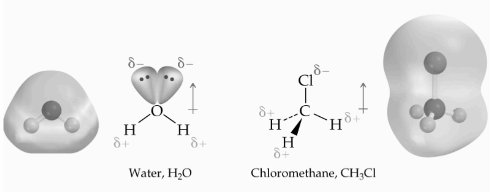
Molecular polarity is represented by an arrow pointing at the negative end and is crossed at the positive end to resemble a positive sign.

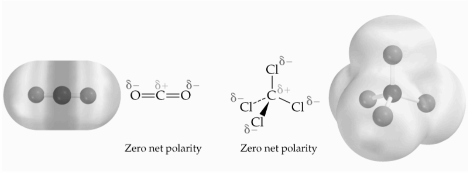


Water, H_2O Chloromethane, CH_3Cl

*Asymmetric molecules are **polar***

MAR

Molecular polarity depends on the shape of the molecule as well as the presence of polar covalent bonds and lone-pairs

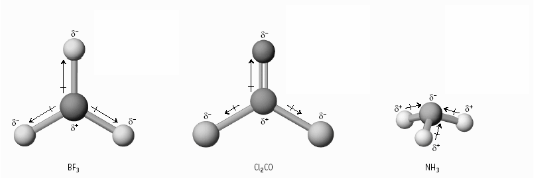


Symmetric molecules are ***nonpolar***

MAR

Test Yourself

Are BF_3, Cl_2CO, and NH_3 polar or nonpolar?



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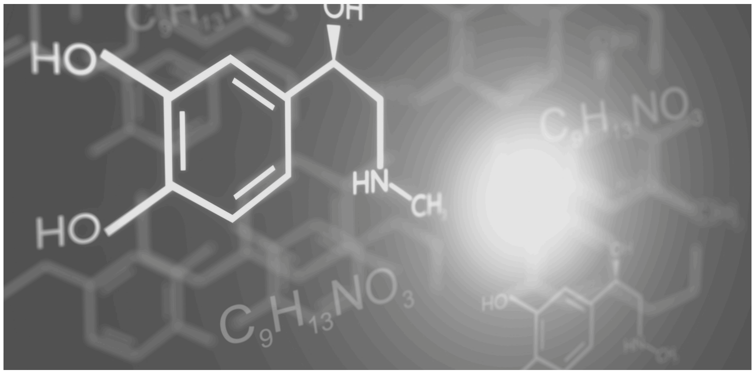
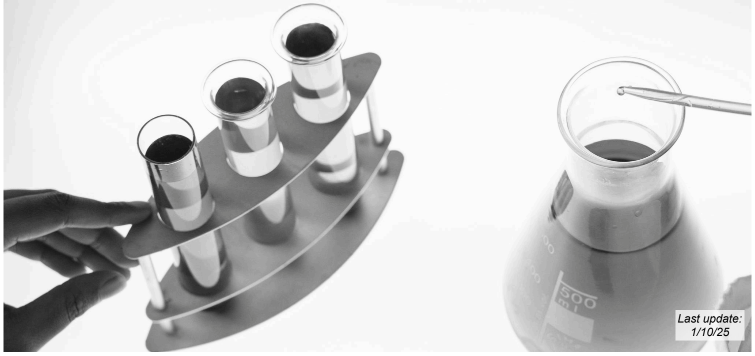
End of Chapter 4 Sections 4.4 - 4.6



Chemistry 151: Basic Chemistry

Chapter 3 Sections 3.3-3.5: Understanding Electrons

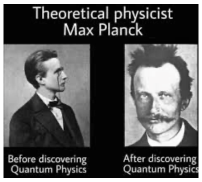


Electrons in Atoms

From previous sections, we know that protons and neutrons are in the nucleus... but what about the electrons?

Most of chemical reactions involve transferring electrons from reactant(s) to product(s), so knowledge of their location is critical.

Quantum physics delivers us answers... but they might make you think twice about the nature of our reality!



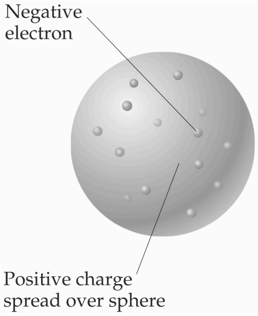
MAR

The Plum Pudding Model of the Atom

JJ Thomson (discoverer of the electron) proposed the "plum pudding" model for the atom (and electrons) in 1904.

Large volume, negative "spheres" in a positive "cloud" of low density

Rutherford's Gold Foil Experiment proposed the correct (current) model *for the nucleus*

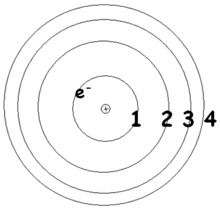


MAR

The Bohr Model of the Atom

Niels Bohr proposed electrons exist in "orbits" - *shells* - around an atom

Electrons want to have the lowest energy possible, thus will occupy orbits closest to the nucleus (the ground state) – unless energy is added to the atom.



Ground state (lowest energy electronic configuration) for the Hydrogen atom.

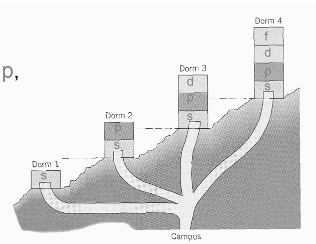
MAR

Limitations of the Bohr Model

Bohr model worked great for H, not so great for other atoms

Schrödinger and others built a better model: **quantum mechanics**, where energy levels are split into *subshells* labeled s, p, d, and f.

The maximum number of sub-levels per energy level = energy level number



Floors within a Dorm
The floors represent different subdivisions of energy within each dorm, analogous to the subshells within each shell

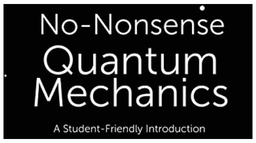
MAR

Electronic Structure of Atoms

Quantum mechanical model of atomic structure gives info on electrons

Electrons *restricted* to moving within a certain region of space in atom - not free to "move about".

Position depends on the amount of energy the electron has.



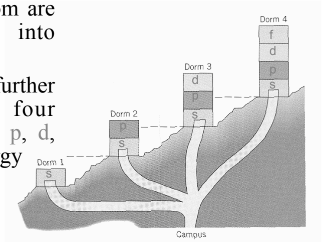
MAR

Electronic Structure of Atoms

Energies of electrons are quantized, or restricted to having only certain values.

This means that electrons in an atom are grouped around the nucleus into shells.

Within the shells, electrons are further grouped into **subshells** of four different types, identified as s, p, d, and f, in order of increasing energy



Floors within a Dorm

The floors represent different subdivisions of energy within each dorm, analogous to the subshells within each shell

Shell number:	1	2	3	4
Subshell designation:	*s*	*s* , *p*	*s* , *p* , *d*	*s* , *p* , *d* , *f*

From quantum mechanics we find:

- The first shell has only a *s* subshell
- The second shell has a *s* and *p* subshell
- The third shell has a *s*, *p* and *d* subshell.
- The fourth shell has a *s*, *p*, *d*, and *f* subshell.

The number of subshells is equal to the shell number (*ex:* shell number 3 has 3 subshells)

Within each subshell, electrons are further grouped into *orbitals*, regions of space within an atom where the electrons are likely to be found. Each orbital holds *two electrons*.

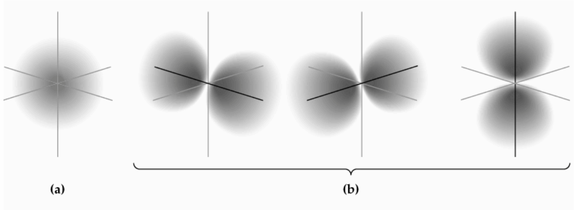
There are different numbers of orbitals within the various subshells:

Shell number:	1	2		3			4			
Subshell designation:	*s*	*s*	*p*	*s*	*p*	*d*	*s*	*p*	*d*	*f*
Number of orbitals:	1	1	3	1	3	5	1	3	5	7

Shapes of Orbitals

Orbitals have different shapes:

- Orbitals in *s* subshells are spherical (a, below)
- Orbitals in *p* subshells are roughly dumbbell / infinity shaped (b, below)



The overall electron distribution within an atom:

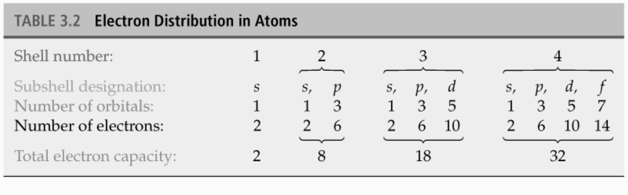


TABLE 3.2 Electron Distribution in Atoms

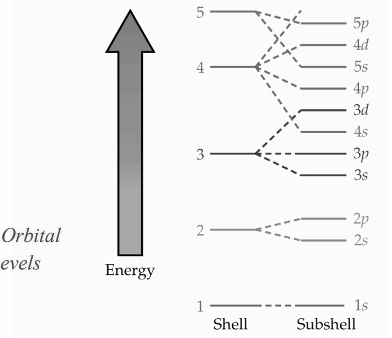
Shell number:	1	2		3			4			
Subshell designation:	*s*	*s,*	*p*	*s,*	*p,*	*d*	*s,*	*p,*	*d,*	*f*
Number of orbitals:	1	1	3	1	3	5	1	3	5	7
Number of electrons:	2	2	6	2	6	10	2	6	10	14
Total electron capacity:	2	8		18			32			

Electron Configurations

Electron Configuration: The *exact* arrangement of electrons in atom's shells and subshells. ***Rules to predict electron configurations:***

- Electrons occupy the lowest-energy orbitals available, beginning with 1s and continuing in order shown on the next slide
- Each orbital holds only two electrons which must have *opposite spin* ("up" and "down")
- *If two or more orbitals with the same energy:* each orbital gets one electron before any orbital gets two.

Notice *order* of electron filling… *important!*
Each orbital holds *only* two electrons



Order of Orbital Energy Levels

MAR

Electron Configurations - *Overview*

Electron Configurations

MAR

Ground State Electron Configurations

Fill electrons into the lowest energy sublevels first.

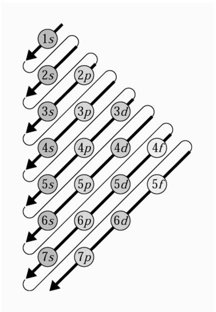
Relative energy of sublevels:
1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s

Procedure:
Start with a bare nucleus and fill electrons into the lowest energy sublevel first (1s), then moving on when each sublevel reaches its maximum number of electrons. Stop when you run out of electrons.
Each s subshell holds 2 electrons; each p subshell holds 6, d holds 10, f holds 14, etc.

This means that 1s, 2s, 3s, 4s, etc. - each of them holds only 2 electrons!
Likewise 2p, 3p, 4p, etc. holds 6 electrons, etc.

MAR

The Aufbau Diagram



Aufbau diagram shows electron filling order (start at 1s and move down by arrow)

Each *s* orbital holds 2 electrons

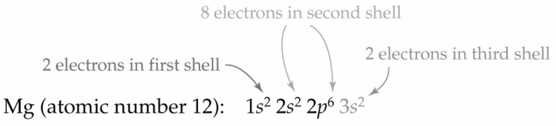
Each *p* orbital holds 6 electrons

Each *d* orbital holds 10 electrons

Each *f* orbital holds 14 electrons

MAR

Electronic configuration of Magnesium:
Magnesium (Z=12) has 12 protons and 12 electrons



Mg (atomic number 12): $1s^2\ 2s^2\ 2p^6\ 3s^2$

Electronic configuration of Boron:
Boron (Z=5) has 5 protons and 5 electrons

B $1s^2\ 2s^2\ 2p^1$ or $\underset{1s^2}{\uparrow\downarrow}\ \ \underset{2s^2}{\uparrow\downarrow}\ \ \underbrace{\uparrow\ \_\ \_}_{2p^1}$

MAR

Orbital Box Notation

Boron shown with "spectroscopic" *($1s^2\ 2s^2\ 2p^1$)* and orbital box notation (on the right)

Orbital box shows if atoms are **paramagnetic** (odd electron by itself) or **diamagnetic** (every up electron has a down electron.)

When filling in electrons, use 1 electron per box in a subshell, only pair when no more empty orbitals

B $1s^2\ 2s^2\ 2p^1$ or $\underset{1s^2}{\uparrow\downarrow}\ \ \underset{2s^2}{\uparrow\downarrow}\ \ \underbrace{\uparrow\ \_\ \_}_{2p^1}$

Boron is paramagnetic (up electron without down)

MAR

Orbital Box Notation

Boron is *paramagnetic* (one unpaired single electron in 2p subshell)

B $1s^2\,2s^2\,2p^1$ or $\underset{1s^2}{\underline{\uparrow\downarrow}}\ \ \underset{2s^2}{\underline{\uparrow\downarrow}}\ \ \underbrace{\underline{\uparrow}\ \underline{\ \ }\ \underline{\ \ }}_{2p^1}$

Magnesium is *diamagnetic* (every "up" electron has a "down" electron, no unpaired electrons)

Mg $\underset{1s^2}{\underline{\uparrow\downarrow}}\ \ \underset{2s^2}{\underline{\uparrow\downarrow}}\ \ \underbrace{\underline{\uparrow\downarrow}\ \underline{\uparrow\downarrow}\ \underline{\uparrow\downarrow}}_{2p^6}\ \ \underset{3s^2}{\underline{\uparrow\downarrow}}$

Paramagnetic species affected by magnetic fields, more reactive

MAR

paramagnetic

C $1s^2\,2s^2\,2p^2$ or $\underset{1s^2}{\underline{\uparrow\downarrow}}\ \ \underset{2s^2}{\underline{\uparrow\downarrow}}\ \ \underbrace{\underline{\uparrow}\ \underline{\uparrow}\ \underline{\ \ }}_{2p^2}$

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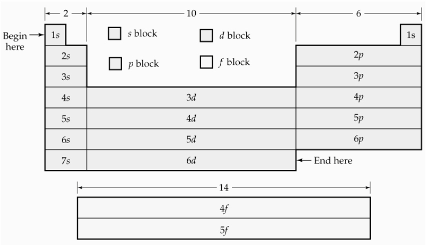
Electron Configurations and the Periodic Table

The periodic table can be divided into four regions or blocks of elements according to the shells and subshells as shown on next slide:



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Test Yourself: Electron Configurations

H: $1s^1$

He: $1s^2$

Li: $1s^2 2s^1$

Be: $1s^2 2s^2$

These are "s-block" elements

B:

C:

N:

O:

F:

Ne:

MAR

For Sodium:

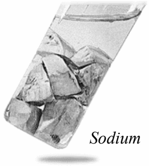
Group 1A

Atomic number = 11

$1s^2\,2s^2\,2p^6\,3s^1$ *or*

"neon core" + $3s^1$

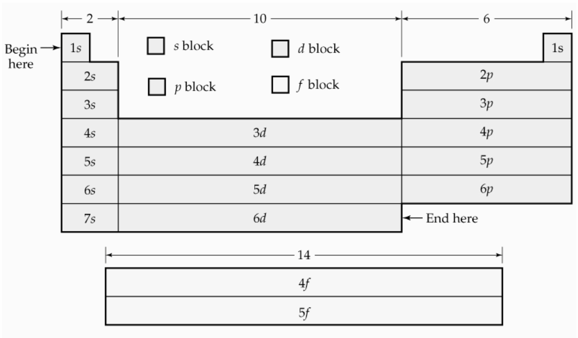
[Ne] $3s^1$ *(uses noble gas notation)*



All Group 1A elements have [core] ns^1 *configurations:*

- **K: [Ar] $4s^1$**
- **Rb: [Kr] $5s^1$**
- **Cs: [Xe] $6s^1$**

MAR



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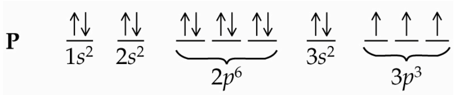
Electron configurations and the periodic table

Valence Shell and Electrons

Valence Shell: Outermost shell of an atom.

Valence electrons: Electrons in the outermost shell of an atom. These electrons are loosely held and are most important in determining an element's properties and reactivities. *Example:*



P has five valence electrons ($3s^2 3p^3$) in the 3rd valence shell

MAR

Valence Electrons

Valence electrons are those in the outermost energy level (the highest main energy level) in an atom. These are the most reactive elements in an atom!

Shortcut: the number of valence electrons = the group number

Ex: Carbon - Group IV - 4 valence electrons

Ex: Bromine - Group VII - 7 valence electrons

MAR

Test Yourself

What is the electron configuration for As?

How many valence electrons in As?

What is the electron configuration for Ca? How many valence electrons in Ca?

MAR

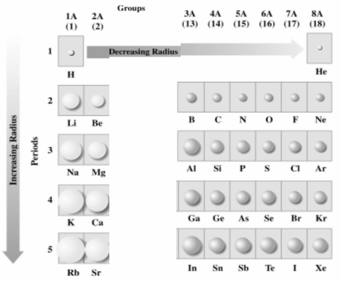
Periodic Properties: Atomic Size

Periodic Properties: properties of elements that repeat in a regular fashion as atomic number increases.

Atomic Size

Atomic size is described using the **atomic radius**; the distance from the nucleus to the valence electrons.

Size gets bigger as you go left and down the periodic table



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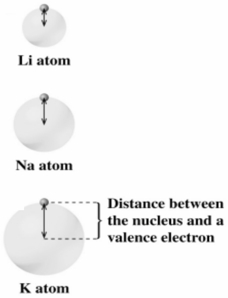
Atomic Radius Within A Group

Atomic radius *increases* going down each group of representative elements.



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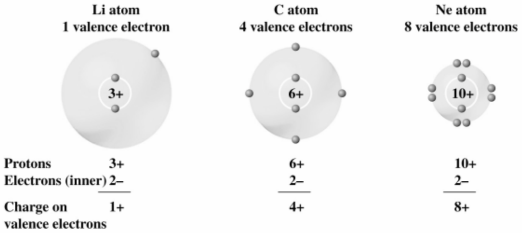
Atomic Radius Across a Period

Going across a period left to right,

- an increase in number of protons increases attraction for valence electrons.
- atomic radius *decreases*.



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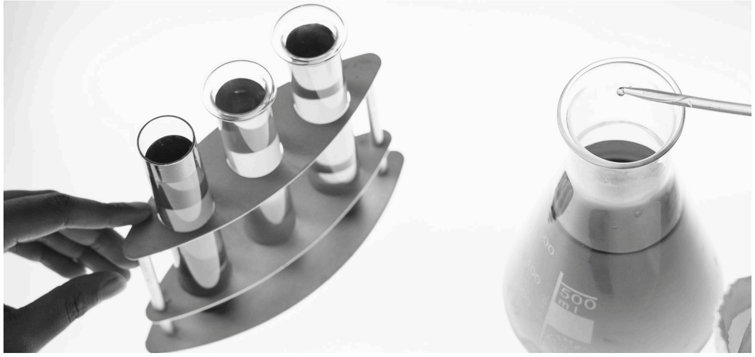
Test Yourself

Which neutral atom is larger: calcium or bromine?

Which neutral atom is larger: calcium or radium?

MAR

End of Chapter 3 Sections 3.3 - 3.5



CH 151 Name: ____________________

Dimensional Analysis Worksheet

Directions: You must show all work and it must be presented in a neat and orderly fashion. The numbers in your setups and answers must include proper units and significant figures. You must use proper dimensional analysis technique, which means use one continuous conversion. **Answers appear immediately following the problems.**

---

1. Convert 124.0 days into seconds.

2. Convert 9.75 x 10^7 fluid ounces of water (density = 0.99998 g/mL) into metric tons.

3. Convert 3.87 x10^{-8} km into cm.

4. Convert 67 U.S. quarts into kL.

5. Convert 6.5 pounds into cups if the density of the liquid is 2.03 g/L.

6. Convert 3.409 miles per hour into km per minute.

7. Convert 56.2 m^3 into yd^3.

8. What is the density of a mystery liquid in g per mL if 65.0 fluid ounces weighs 202 mass ounces?

9. A piece of gold leaf (density 19.3 g/cm^3) weighs 1.93 mg. What is the volume in mm^3?

10. What is a better deal, a one gallon gasoline for $2.89 or one liter of gasoline for $0.75? Support you answer using calculations.

11. A car travels at a rate of 65 miles per hour. If the car gets 33.5 miles to the gallon, how many hours can a car travel on 25.0 pounds of fuel? (density of fuel is 6.50 pounds/gallon)

12. The recommended dose of a medication is 5 mg/kg body weight. You have a patient whose weight is 125 pounds. The pharmacy offers three different oils containing 500 mg, 250 mg, and 100 mg of medication. Which pill should you give your patient?

13. The bromine content of the ocean is about 65 grams of bromine per million grams of sea water. How many cubic meters of ocean must be processed to recover 1.0 pounds of bromine if the density of sea water is 1.0×10^3 kg/m^3?

14. An average man is requires about 2.00 mg of fiboflavin (vitamin B2) per day. Cheese contains 5.5µg of riboflavin per gram of cheese. How many pounds of cheese would a man have to eat per day if this is his only source of riboflavin?

15. Alan is going to the Boy Scouts Jamboree in D.C. next summer and he has been asked to bring the smores supply for all the boys going from the district in Oregon. Each giant chocolate bar makes 16 smores. Each boy will be limited to exactly 3 smores. The problem is that he has to buy the chocolate once he gets to D.C. because there will be too many of them and they may melt in the summer heat. On average, the stores only carry 25 of these giant chocolate bars in stock. How many stores will he have to visit if there are 2,225 boys?

16. In the yearly fundraiser at school, kids can earn a hamburger phone if they raise at least $250 in donations. Aaron was able to get all of his family and family friends to pledge enough money that he will earn $35 for each mile he runs. The problem is he runs very slowly, 88 inches per second. How many hours will it take him to run just long enough to earn the hamburger phone?

Answers to the Dimensional Analysis Worksheet:

1. $1.071 * 10^7$ s
2. $2.88 * 10^3$ tons
3. $3.87 * 10^{-3}$ cm
4. $6.3 * 10^{-2}$ kL
5. $6.1 * 10^3$ cups
6. $9.142 * 10^{-2}$ km
7. 73.6 yd^3
8. 2.98 g/mL
9. 0.100 mm^3
10. $0.75/L (which equals $2.84 / gallon)
11. 2.0 hr
12. Use 250 mg pill (answer = 300 mg)
13. 7.0 m^3
14. 0.80 lb
15. 17 stores
16. 1.4 hr

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Common Polyatomic Ions and the Corresponding Acids

There is a pattern associated with many of the polyatomic ions in chemistry that can aid you when learning names and the relationships with the corresponding acids. Some combinations of a central atom with oxygen are found more often in nature, and they are designated the "common" form of the polyatomic... yet due to oxygen's "social nature", several other combinations of the central atom with oxygen can exist. A pattern exists which relates the number of oxygen atoms relative to the "common" form... and this pattern can be extended to a host of oxygen-containing acids.

First, remember this phrase:

"**Nick** the **Camel Brat** ate **Icky Clam** for **Supper** in **Phoenix**"

This phrase helps you remember the **central atom**, the **number of oxygen atoms in the "common" form** of the polyatomic, and the **charge** on the polyatomic ion. ***All of the common form polyatomic ions get an "ate" suffix.***

- The **number of consonants** = the **number of oxygen atoms** in the common form of the polyatomic ion
- The **number of vowels** = the **negative charge** on the polyatomic ion

Nick = **nitr**ate, NO_3^{-1}
Camel = **carb**onate, CO_3^{-2}
Brat = **brom**ate, BrO_3^{-1}
Icky = **iod**ate, IO_3^{-1} *(note that **y** is a consonant and not a vowel in this context!)*
Clam = **chlor**ate, ClO_3^{-1}
Supper = **sulf**ate, SO_4^{-2}
Phoenix = **phosph**ate, PO_4^{-3}

- Polyatomic ions in the **common** form have an "**ate**" suffix (i.e. chlor**ate**, ClO_3^{-1})
- Polyatomic ions with **one more oxygen** than the common form get a "**per**" prefix and an "**ate**" suffix (i.e. **per**chlor**ate**, ClO_4^{-1})
- Polyatomic ions with **one less oxygen** than the common form get an "**ite**" ending (i.e. chlor**ite**, ClO_2^{-1})
- Polyatomic ions with **two less oxygen atoms** than the common form get a "**hypo**" prefix and the "**ite**" suffix (i.e. **hypo**chlor**ite**, ClO^{-1})

The following table shows the various polyatomic ions and all of their known variations:

	nitrogen	*carbon*	*bromine*	*iodine*	*chlorine*	*sulfur*	*phosphorus*
-2 oxygen	-	-	**hypo**brom**ite**, BrO^{-1}	**hypo**iod**ite**, IO^{-1}	**hypo**chlor**ite**, ClO^{-1}	-	-
-1 oxygen	nitr**ite**, NO_2^{-1}	-	brom**ite**, BrO_2^{-1}	iod**ite**, IO_2^{-1}	chlor**ite**, ClO_2^{-1}	sulf**ite**, SO_3^{-2}	phosph**ite**, PO_3^{-3}
common	nitr**ate**, NO_3^{-1}	carbon**ate**, CO_3^{-2}	brom**ate**, BrO_3^{-1}	iod**ate**, IO_3^{-1}	chlor**ate**, ClO_3^{-1}	sulf**ate**, SO_4^{-2}	phosph**ate**, PO_4^{-3}
+1 oxygen	-	-	**per**brom**ate**, BrO_4^{-1}	**per**iod**ate**, IO_4^{-1}	**per**chlor**ate**, ClO_4^{-1}	-	-

Entries with a "-" are not known to exist and can be ignored.

Polyatomic ions readily make acids. An acid is a compound with a hydrogen atom that reacts readily with other substances. In chemistry, we list the acidic hydrogen first to designate its reactivity.

As before, a naming pattern exists for acids containing an oxygenated polyatomic ion:

- Acidic polyatomic ions in the **common** form have an "**ic acid**" suffix (i.e. chlor**ic acid**, $HClO_3$)
- Acidic polyatomic ions with **one more oxygen** than the common form get a "**per**" prefix and an "**ic acid**" suffix (i.e. **per**chlor**ic acid**, $HClO_4$)
- Acidic polyatomic ions with **one less oxygen** than the common form get an "**ous acid**" ending (i.e. chlor**ous acid**, $HClO_2$)
- Acidic polyatomic ions with **two less oxygen atoms** than the common form get a "**hypo**" prefix and the "**ous acid**" suffix (i.e. **hypo**chlor**ous acid**, $HClO$)
- Acidic polyatomic ions with **no oxygen atoms** get a "**hydro**" prefix and the "**ic acid**" suffix (i.e. **hydro**chlor**ic acid**, HCl)

The following table shows the acidic form of the polyatomic ions with all of their known variations:

	nitrogen	*carbon*	*bromine*	*iodine*	*chlorine*	*sulfur*	*phosphorus*
no oxygen	-	-	**hydro**brom**ic** **acid**, HBr	**hydro**iod**ic** **acid**, HI	**hydro**chlor**ic** **acid**, HCl	**hydro**sulfur**ic** **acid**, H_2S	-
-2 oxygen	-	-	**hypo**brom**ous** **acid**, $HBrO$	**hypo**iod**ous** **acid**, HIO	**hypo**chlor**ous** **acid**, $HClO$	-	-
-1 oxygen	nitr**ous** **acid**, HNO_2	-	brom**ous** **acid**, $HBrO_2$	iod**ous** **acid**, HIO_2	chlor**ous** **acid**, $HClO_2$	sulfur**ous** **acid**, H_2SO_3	phosphor**ous** **acid**, H_3PO_3
common	nitr**ic** **acid**, HNO_3	carbon**ic** **acid**, H_2CO_3	brom**ic acid**, $HBrO_3$	iod**ic acid**, HIO_3	chlor**ic acid**, $HClO_3$	sulfur**ic acid**, H_2SO_4	phosphor**ic** **acid**, H_3PO_4
+1 oxygen	-	-	**per**brom**ic** **acid**, $HBrO_4$	**per**iod**ic** **acid**, HIO_4	**per**chlor**ic** **acid**, $HClO_4$	-	-

Finally, please note that this list is not 100% inclusive... but similar patterns can be applied to polyatomic ions not on this list. For example,

- H_2SeO_4 = selenic acid *and* H_2SeO_3 = selenous acid
- AsO_4^{-3} = arsenate ion *and* AsO_3^{-3} = arsenite ion

And if you cannot get enough polyatomic ions… here's another useful phrase:

"**Simon** and **Bonnie** **Aspired** to **Search** the **Creepy** **Count** for the **Icky** **Clam**"

Simon = SiO_3^{2-} = silicate
Bonnie = BO_3^{3-} = borate
Aspired = AsO_4^{2-} = arsenate
Search = SeO_4^{2-} = selenate
Creepy = CrO_4^{2-} = chromate
Count = CO_3^{2-} = carbonate
Icky = IO_3^{1-} = silicate
Clam = ClO_3^{1-} = chlorate

CH 151 Nomenclature
Self Quiz Name: ______________________________ Lab Section: _______

This is a sample quiz for CH 151 providing examples of nomenclature. Answers are provided at the end of this handout. *Good luck!*

Provide names or formulas for the following compounds:

nitrogen trifluoride	nitrogen monoxide	nitrogen dioxide
dinitrogen tetroxide	dinitrogen monoxide	phosphorus trichloride
phosphorus pentachloride	sulfur hexafluoride	disulfur decafluoride
xenon tetrafluoride	CCl_4	P_4O_{10}
ClF_3	BCl_3	SF_4
$HBr(g)$	N_2F_2	XeF_3
PI_3	SCl_2	S_2Cl_2
OF_2	NCl_3	$AsCl_5$

CH 151 Nomenclature
Self Quiz Name: ______________________________ Lab Section: _______

This is a sample quiz for CH 151 providing examples of nomenclature. Answers are provided at the end of this handout. *Good luck!*

Provide a formula for the following combinations of cation and anion:

	Cl^-	NO_3^-	S^{2-}	CO_3^{2-}	N^{3-}	PO_4^{3-}	OH^-
Na^+							
NH_4^+							
Sn^{2+}							
Hg_2^{2+}							
Al^{3+}							
Sn^{4+}							

Provide the formula and name for the following combinations of cations and anions:

Cation	**Anion**	**Formula**	**Name**
Cu^{2+}	OH^-		
Ba^{2+}	SO_4^{2-}		
NH_4^+	$Cr_2O_7^{2-}$		
Ag^+	$C_2H_3O_2^-$		
Fe^{3+}	S^{2-}		

Provide names and/or formulas for the following:

Formula	**Name**
HCl(aq)	
$HBrO_2$(aq)	
H_2SO_4(aq)	
HNO_2(aq)	
HIO(aq)	
HIO_4(aq)	
NaOH	
LiOH	
NH_4OH	
$Mg(OH)_2$	

Formula	**Name**
	hydrobromic acid
	chlorous acid
	sulfurous acid
	hydrosulfuric acid
	nitric acid
	phosphoric acid
	phosphorous acid
	potassium hydroxide
	calcium hydroxide
	dihydrogen monoxide

nitrogen trifluoride **NF_3**	nitrogen monoxide **NO**	nitrogen dioxide **NO_2**
dinitrogen tetroxide **N_2O_4**	dinitrogen monoxide **N_2O**	phosphorus trichloride **PCl_3**
phosphorus pentachloride **PCl_5**	sulfur hexafluoride **SF_6**	disulfur decafluoride **S_2F_{10}**
xenon tetrafluoride **XeF_4**	CCl_4 **carbon tetrachloride**	P_4O_{10} **tetraphosphorus decaoxide**
ClF_3 **chlorine trifluoride**	BCl_3 **boron trichloride**	SF_4 **sulfur tetrafluoride**
HBr(g) **hydrogen monobromide** *(not an acid)*	N_2F_2 **dinitrogen difluoride**	XeF_3 **xenon trifluoride**
PI_3 **phosphorus triiodide**	SCl_2 **sulfur dichloride**	S_2Cl_2 **disulfur dichloride**
OF_2 **oxygen difluoride**	NCl_3 **nitrogen trichloride**	$AsCl_5$ **arsenic pentachloride**

CH 151 Nomenclature *Self Quiz* - **ANSWERS APPEAR IN BOLD**

Provide a formula for the following combinations of cation and anion:

	Cl^-	NO_3^-	S^{2-}	CO_3^{2-}	N^{3-}	PO_4^{3-}	OH^-
Na^+	**$NaCl$**	**$NaNO_3$**	**Na_2S**	**Na_2CO_3**	**Na_3N**	**Na_3PO_4**	**$NaOH$**
NH_4^+	**NH_4Cl**	**NH_4NO_3**	**$(NH_4)_2S$**	**$(NH_4)_2CO_3$**	**$(NH_4)_3N$**	**$(NH_4)_3PO_4$**	**NH_4OH**
Sn^{2+}	**$SnCl_2$**	**$Sn(NO_3)_2$**	**SnS**	**$SnCO_3$**	**Sn_3N_2**	**$Sn_3(PO_4)_2$**	**$Sn(OH)_2$**
Hg_2^{2+}	**Hg_2Cl_2**	**$Hg_2(NO_3)_2$**	**Hg_2S**	**Hg_2CO_3**	**$(Hg_2)_3N_2$**	**$(Hg_2)_3(PO_4)_2$**	**$Hg_2(OH)_2$**
Al^{3+}	**$AlCl_3$**	**$Al(NO_3)_3$**	**Al_2S_3**	**$Al_2(CO_3)_3$**	**AlN**	**$AlPO_4$**	**$Al(OH)_3$**
Sn^{4+}	**$SnCl_4$**	**$Sn(NO_3)_4$**	**SnS_2**	**$Sn(CO_3)_2$**	**Sn_3N_4**	**$Sn_3(PO_4)_4$**	**$Sn(OH)_4$**

Provide the formula and name for the following combinations of cations and anions:

Cation	**Anion**	**Formula**	**Name**
Cu^{2+}	OH^-	**$Cu(OH)_2$**	**copper(II) hydroxide**
Ba^{2+}	SO_4^{2-}	**$BaSO_4$**	**barium sulfate**
NH_4^+	$Cr_2O_7^{2-}$	**$(NH_4)_2Cr_2O_7$**	**ammonium dichromate**
Ag^+	$C_2H_3O_2^-$	**$AgC_2H_3O_2$**	**silver(I) acetate**
Fe^{3+}	S^{2-}	**Fe_2S_3**	**iron(III) sulfide**

Provide names and/or formulas for the following:

Formula	**Name**
$HCl(aq)$	**hydrochloric acid**
$HBrO_2(aq)$	**bromous acid**
$H_2SO_4(aq)$	**sulfuric acid**
$HNO_2(aq)$	**nitrous acid**
$HIO(aq)$	**hypoiodous acid**
$HIO_4(aq)$	**periodic acid**
$NaOH$	**sodium hydroxide**
$LiOH$	**lithium hydroxide**
NH_4OH	**ammonium hydroxide**
$Mg(OH)_2$	**magnesium hydroxide**

Formula	**Name**
$HBr(aq)$	hydrobromic acid
$HClO_2(aq)$	chlorous acid
$H_2SO_3(aq)$	sulfurous acid
$H_2S(aq)$	hydrosulfuric acid
$HNO_3(aq)$	nitric acid
$H_3PO_4(aq)$	phosphoric acid
$H_3PO_3(aq)$	phosphorous acid
KOH	potassium hydroxide
$Ca(OH)_2$	calcium hydroxide
H_2O	dihydrogen monoxide

CH 151 "Mass, Moles, Atoms" Study Questions

1. What is the molar mass of ammonium sulfate?

2. What is the molar mass of cobalt(II) iodide hexahydrate?

3. Calculate the number of moles in 0.41 g of titanium.

4. What is the mass of $1.0 * 10^9$ carbon atoms?

5. The density of carbon tetrachloride is 1.59 g/mL. How many Cl atoms are present in 55 mL of carbon tetrachloride?

6. The molar mass of cesium is 132.9 g/mol. What is the mass of a single Cs atom?

7. The density of lithium is 0.546 g/cm^3. What volume is occupied by $1.96 \text{ x } 10^{23}$ atoms of Li?

8. What is the mass percentage of oxygen in acetic acid, HCH_3CO_2?

9. Which of the following could be an empirical formula? C_6H_{10}, B_4H_{10}, NO_3, $AsCl_5$.

10. Benzene has an empirical formula of CH. If the molar mass of benzene is 78.11 g/mol, what is the molecular formula for benzene?

11. Toluene is 91.25% C and 8.75% H. Determine the empirical formula for toluene. *Hint:* 8/7 = 1.14

12. The compound azulene is 93.71%C with the remainder hydrogen, and it has a molar mass of 128.16 g/mol. Calculate the empirical formula and molecular formula for azulene. *Hint:* 5/4 = 1.25

Answers appear on the next page

CH 151 "Mass, Moles, Atoms" Study Questions - *Answers*

1. 132.1 g/mol
2. 420.8 g/mol
3. 8.6×10^{-3} mol
4. 2.0×10^{-14} g
5. 1.4×10^{24} atoms
6. 2.207×10^{-22} g
7. 4.14 cm^3
8. 53.29%
9. NO_3 and $AsCl_5$ could be empirical formulas.
10. C_6H_6
11. C_7H_8
12. C_5H_4 (EF) and $C_{10}H_8$ (MF)

CH 151 Name: ____________________

Chemical Reactions Worksheet

Directions: Balance the following chemical reactions using the given information. In addition, ***classify*** each chemical reaction. **Answers appear immediately following the problems.**

---

1. Hypochlorous acid decomposes into water and dichlorine monoxide.

Reaction classification: _______________

2. Acetic acid is burned.

Reaction classification: _______________

3. Solid magnesium fluoride appears upon mixing magnesium chloride and sodium fluoride.

Reaction classification: _______________

4. Phosphorus (P_4) and oxygen produce tetraphosphorus decaoxide.

Reaction classification: _______________

5. Calcium and hydrochloric acid create a gas. Identify the gas through the balanced equation.

Reaction classification: _______________

6. Calcium hydroxide is added to perchloric acid..

Reaction classification: _______________

***Answers* to the Chemical Reactions Worksheet:**

---

1. Hypochlorous acid decomposes into water and dichlorine monoxide.

$\mathbf{2\ HClO(aq) \rightarrow H_2O(l) + Cl_2O(aq)}$ *Classification:* **Decomposition**

2. Acetic acid is burned.

$\mathbf{HC_2H_3O_2(aq) + 2\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(l)}$ *Classification:* **Combustion / Burning**

3. Solid magnesium fluoride appears upon mixing magnesium chloride and sodium fluoride.

$\mathbf{MgCl_2(aq) + 2\ NaF(aq) \rightarrow MgF_2(s) + 2\ NaCl(aq)}$ *Classification:* **Precipitation**

4. Phosphorus (P_4) and oxygen produce tetraphosphorus decaoxide.

$\mathbf{P_4(s) + 5\ O_2(g) \rightarrow P_4O_{10}(s)}$ *Classification:* **Combination**

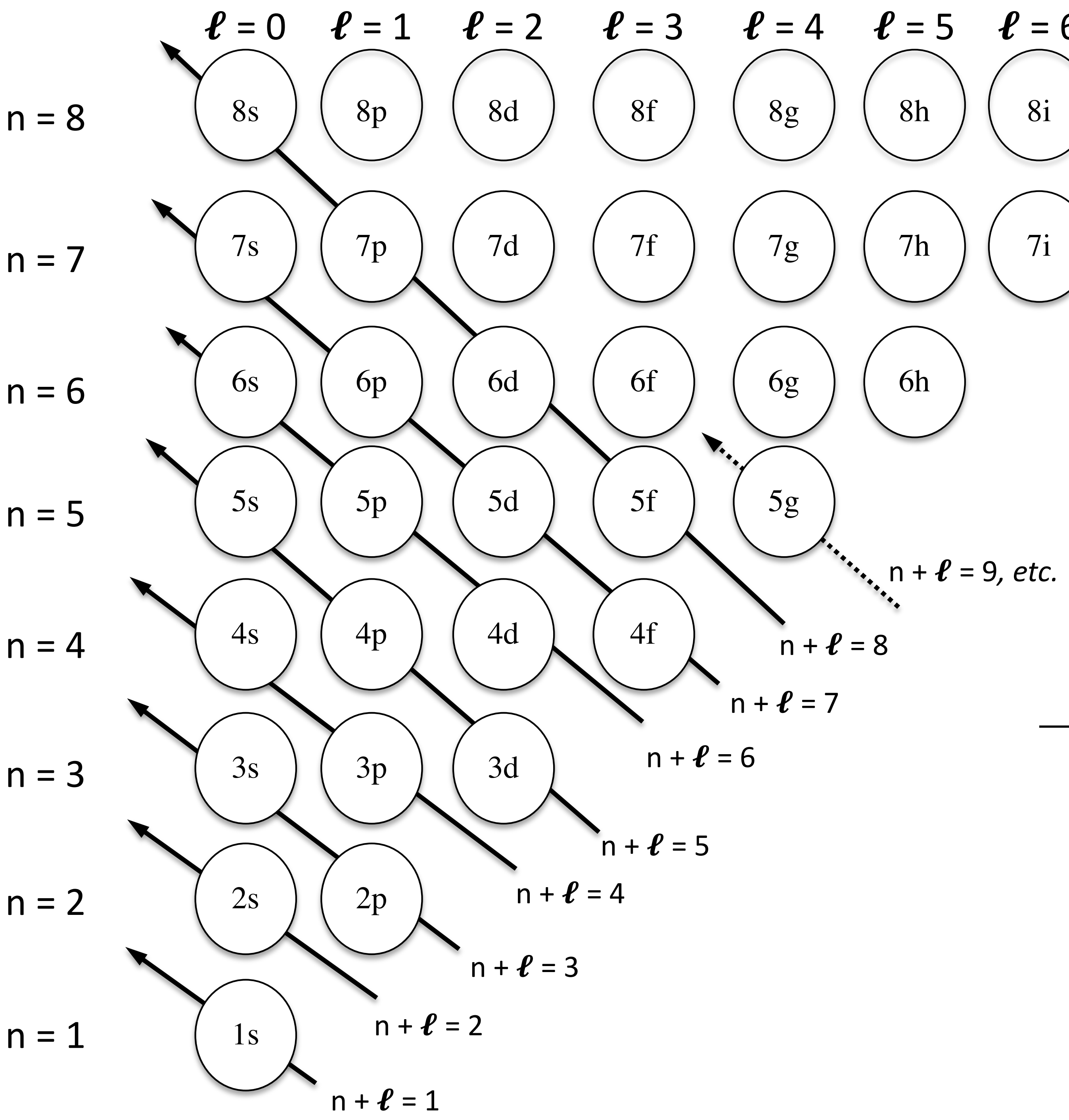
5. Calcium and hydrochloric acid create a gas. Identify the gas through the balanced equation.

$\mathbf{Ca(s) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)}$ *Classification:* **Single Replacement**

6. Calcium hydroxide is added to perchloric acid..

$\mathbf{Ca(OH)_2(aq) + 2\ HClO_4(aq) \rightarrow Ca(ClO_4)_2(aq) + 2\ H_2O(l)}$ *Classification:* **Acid/Base**

Aufbau Diagram



ℓ	letter	
0	s	*stupid*
1	p	*people*
2	d	*drive*
3	f	*freakin’*
4	g	*gas*
5	h	*hogs*

1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p…

Predicting Atomic Electron Configurations

1) Electrons occupy the lowest energy orbitals available - *the **n+l Rule***
Begin assigning electrons at **1s** and continue in the following order:

1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p *etc.*

Examples: **Li**: $1s^2 2s^1$ **Na**: $1s^2 2s^2 2p^6 3s^1$ **Ca**: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

2) **s** orbitals have one subshell; **p** orbitals have three subshells; **d** orbitals have five subshells; **f** orbitals have seven subshells. Or:

Number of subshells = 2l+1

where $\mathbf{m_l = \{l, (l-1), \ldots, 0, \ldots, (-l+1), -l\}}$ … *and* $\mathbf{l = \{0, 1, \ldots n - 1\}}$

3) No two electrons in an atom can have the same set of four quantum numbers - ***Pauli Exclusion Principle***. Each subshell can hold only two electrons, and the two electrons must have opposite values of spin (i.e. $\mathbf{m_s}$).

4) The most stable arrangement of electrons is that with the maximum number of unpaired electrons - ***Hund's Rule***. Single electrons must occupy every subshell in an orbital before they "pair up" or are "spin paired".

Example: **Ti**: $[Ar]3d^2 4s^2$ Titanium has two unpaired electrons

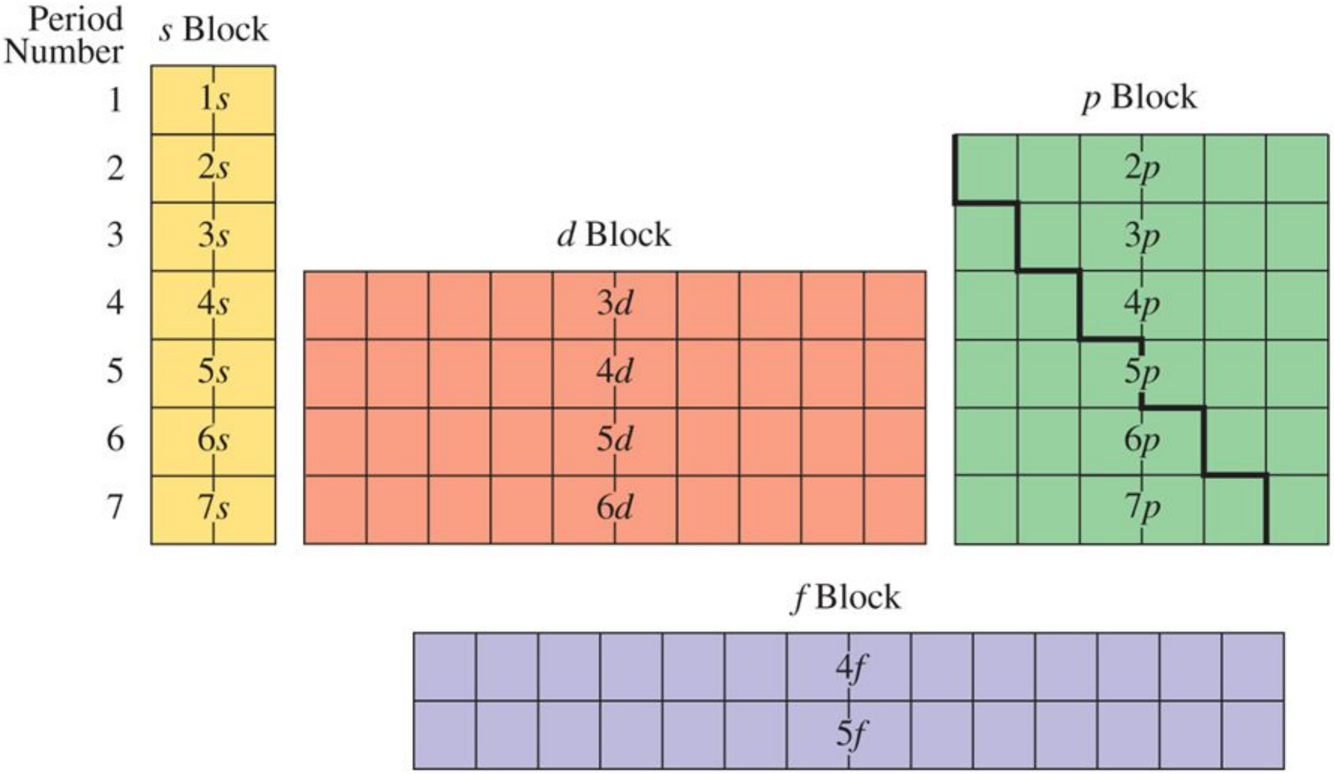
5) ***Paramagnetic*** compounds contain unpaired electrons.
Diamagnetic compounds contain electrons that are exclusively "spin paired." No unpaired electrons exist in diamagnetic compounds.

Examples: **Zn**: $[Ar]3d^{10} 4s^2$ *(diamagnetic*) **Li**: $[He]2s^1$ *(paramagnetic)*

6) ***Atomic ion configurations*** can be assigned using the rules given above and while remembering that the electrons easiest to remove will generally come from the highest energy orbital available.

Examples: **Cu**: $[Ar]3d^{10} 4s^1$ $\mathbf{Cu^{2+}}$: $[Ar]3d^9$

Periodic Table Blocks



CH 151 Study Questions for the Final Exam

1. If 97.0 grams of aluminum oxide is produced from the reaction of 65.0 grams of aluminum with unlimited oxygen, what is the theoretical yield of aluminum oxide and the percent yield?
2. If 0.885 g of CO react with 0.352 g of H_2 to form CH_3OH, what is the limiting reactant? What is the theoretical yield of CH_3OH? What mass of excess reactant is left at the end of the reaction?
3. How many grams are there in 5.62×10^{13} molecules of $C_8H_{18}O_4$?
4. How many atoms of nitrogen are in 6.5×10^6 g of $Al(NO_3)_3$?
5. How many atoms of chlorine are there in 943.1 g of chlorine (Cl_2)?
6. Gallium reacts with iodine to make gallium iodide. Write the balanced equation.
7. Lead(II) nitrate reacts in a double displacement reaction with sodium iodide. Write the balanced equation.
8. Write the electron configuration for the following atoms: Ne, Mg, Cl, Ca, V, Kr
9. Write the electron configuration for the following ions: Na^+, Al^{3+}, F^{-1}, Cr^{5+}.
10. In questions #8 and #9, above, which atoms and ions are paramagnetic? Which atom or ion is the *most* paramagnetic?
11. In questions #8 and #9, above, which atoms and ions are isoelectronic? How many valence electrons do the isoelectronic atoms and/or ions possess?

Answers appear on the next page

CH 151 Study Questions for the Final Exam - *Answers*

1. 123 g Al_2O_3, 78.9% yield
2. CO limiting reactant, 1.01 g = theoretical yield, 0.224 g excess reactant unused
3. $1.66 * 10^{-8}$ g
4. $5.5 * 10^{28}$ atoms N
5. $1.602 * 10^{25}$ atoms Cl
6. $2\ Ga + 3\ I_2 \rightarrow 2\ GaI_3$
7. $Pb(NO_3)_2 + 2\ NaI \rightarrow 2\ NaNO_3 + PbI_2$
8. Ne: $1s^22s^22p^6$, Mg: $[Ne]3s^2$, Cl: $[Ne]3s^23p^5$, Ca: $[Ar]4s^2$, V: $[Ar]4s^23d^3$, Kr: $[Ar]4s^23d^{10}4p^6$
9. Na^+: [Ne], Al^{3+}: [Ne], F^{-1}: [Ne], Cr^{5+}: $[Ar]3d^1$
10. *Paramagnetic:* Cl (1 unpaired electrons), Vanadium (3 unpaired electrons), chromium(V) (1 unpaired electron). Vanadium is the most paramagnetic.
11. *Isoelectronic:* Ne, Na^+, Al^{3+}, F^{-1}. These species have zero valence electrons.

CH 151 Sample Quiz #1 Name: ______________________________

Be sure to show all work, use the correct number of significant figures, circle final answers and use correct units in all problems.

---

1. Automotive batteries generally are filled with sulfuric acid. If a battery has a volume of 1.86 L and contains 3.42 x 10^6 mg of sulfuric acid, what is the density of sulfuric acid in g/mL? (5 points)

2. A child's fever medicine has a concentration of 250 mg/mL. If a child receives 2.0 teaspoons of this medicine, how many mg of medicine is being received? (1 teaspoon = 4.93 mL) (5 points)

3. Perform the following calculations. Report the answer to the correct number of significant digits. (5 points)

110.23 cm + 0.989 cm + 1.20 cm ______________

$$\frac{\left(2.34 \text{ x } 10^{3} \text{ cm}\right)\left(4.2021 \text{ x } 10^{-6} \text{ cm}\right)}{\left(8.7 \text{ x } 10^{3}\text{s}\right)}$$ ______________

154.0 = 3.76 x Q Q = ______________

4. Convert the following quantities: (5 points) Watch sig figs!

157.7 K to **°C**.

9.22 g/cm^3 to **g/mm^3**

7.360 cg to **ng**

CH 151
Sample Quiz #1 Name: ____ Lab Section: _______
Answers

---

1. Automotive batteries generally are filled with sulfuric acid. If a battery has a volume of 1.86 L and contains 3.42 x 10^6 mg of sulfuric acid, what is the density of sulfuric acid in g/mL? (5 points)

   1.84 g/ mL

2. A child's fever medicine has a concentration of 250 mg/mL. If a child receives 2.0 teaspoons of this medicine, how many mg of medicine is being received? (1 teaspoon = 4.93 mL) (5 points)

   2500 mg

3. Perform the following calculations. Report the answer to the correct number of significant digits. (5 points)

   110.23 cm + 0.989 cm + 1.20 cm ***112.42 cm***

   $$\frac{\left(2.34 \text{ x } 10^{3} \text{ cm}\right)\left(4.2021 \text{ x } 10^{-6} \text{ cm}\right)}{\left(8.7 \text{ x } 10^{3}\text{s}\right)}$$ **1.1 x 10^{-6} cm^2 / s**

   154.0 = 3.76 x Q Q = **41.0**

4. Convert the following quantities: (5 points) Watch sig figs!

   157.7 K to **°C**. **-115.5 °C**

   9.22 g/cm^3 to **g/mm^3** **9.22 x 10^{-3} g/mm^3**

   7.360 cg to **ng** **7.360 x 10^7 ng**

CH 151 Sample Quiz #2a Name: ____

Be sure to show all work, use the correct number of significant figures, circle final answers and use correct units in all problems.

---

1. Match the term on the left with the correct phrase on the right (7 points)

A. Isotope	__	Smallest subatomic particle; negative charge
B. Atomic Number	__	Same atomic number, different mass number
C. Neutron	__	Positive subatomic particle
D. Mass Number	__	Same mass number, different atomic number
E. Proton	__	Largest subatomic particle
F. Electron	__	Number of protons
G. Isobar	__	Number of protons and neutrons

2. Calculate the atomic number and mass number for an atom with 30 protons, 34 neutrons and 28 electrons. What element is it? What is the atom's symbol? Give the symbol for this isotope in the form $^{A}_{Z}X$. (5 points)

3. Classify each of the statements below as being True (**T**) or false (**F**). (1 point each, 8 points total)

An elemental symbol contains a capital letter followed by a small letter __

The properties of elements are always different from the properties of the compounds they formed __

Two objects, both having a negative charge, attract each other __

Two atoms of silicon each with a different number of electrons will always have the same mass number __

The mass number for each isotope of an element will be different __

Protons and electrons act like a type of "glue" that holds the atom together __

Democritus determined that most of the atom was empty __

An isotope of neptunium with 93 neutrons is written as neptunium-93 __

CH 151
Sample Quiz #2a Name: ____ Lab Section: _______
Answers

---

1. Match the term on the left with the correct phrase on the right (7 points)

A. Isotope	**F**	Smallest subatomic particle; negative charge
B. Atomic Number	**A**	Same atomic number, different mass number
C. Neutron	**E**	Positive subatomic particle
D. Mass Number	**G**	Same mass number, different atomic number
E. Proton	**C**	Largest subatomic particle
F. Electron	**B**	Number of protons
G. Isobar	**D**	Number of protons and neutrons

2. Calculate the atomic number and mass number for an atom with 30 protons, 34 neutrons and 28 electrons. What element is it? What is the atom's symbol? Give the symbol for this isotope in the form ${}^{A}_{Z}X$. (5 points)

This is zinc-64, or $_{30}{}^{64}Zn^{2+}$

3. Classify each of the statements below as being True (**T**) or false (**F**). (1 point each, 8 points total)

An elemental symbol contains a capital letter followed by a small letter	**F**
The properties of elements are always different from the properties of the compounds they formed	**T**
Two objects, both having a negative charge, attract each other	**F**
Two atoms of silicon each with a different number of electrons will always have the same mass number	**F**
The mass number for each isotope of an element will be different	**T**
Protons and electrons act like a type of "glue" that holds the atom together	**T**
Democritus determined that most of the atom was empty	**F**
An isotope of neptunium with 93 neutrons is written as neptunium-93	**F**

CH 151 Sample Quiz #2b Name: ____

Be sure to show all work, use the correct number of significant figures, circle final answers and use correct units in all problems.

---

1. Write the names of the following compounds. Use acid names where appropriate. (1 point each)

P_2S_3

$Mg(NO_2)_2$

HBrO

Cu_2S

$CaCl_2$

N_2O_4

V_2O_3

$SnCl_3$

SiO_2

HI

2. Write the correct formula for each of the following compounds: (1 point each)

potassium bromide

nickel(IV) oxide

sulfur difluoride

galium oxide

nitric acid

iron(II) hydroxide

periodic acid

sodium iodide

sulfur hexafluoride

titanium(II) sulfate

CH 151
Sample Quiz #2b Name: ____ Lab Section: _______
Answers

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1. Write the names of the following compounds. Use acid names where appropriate. (1 point each)

P_2S_3	**diphosphorus trisulfide**
$Mg(NO_2)_2$	**magnesium nitrite**
HBrO	**hypobromous acid**
Cu_2S	**copper(I) sulfide**
$CaCl_2$	**calcium chloride**
N_2O_4	**dinitrogen tetraoxide**
V_2O_3	**vanadium(III) oxide**
$SnCl_3$	**tin(III) chloride**
SiO_2	**silicon dioxide (silicon(IV) oxide ok)**
HI	**hydroiodic acid**

2. Write the correct formula for each of the following compounds: (1 point each)

potassium bromide	**KBr**
nickel(IV) oxide	**NiO_2**
sulfur difluoride	**SF_2**
galium oxide	**Ga_2O_3**
nitric acid	**HNO_3**
iron(II) hydroxide	**$Fe(OH)_2$**
periodic acid	**HIO_4**
sodium iodide	**NaI**
sulfur hexafluoride	**SF_6**
titanium(II) sulfate	**$TiSO_4$**

CH 151 Sample Quiz #3 Name: ______________________________

Be sure to show all work, use the correct number of significant figures, circle final answers and use correct units in all problems.

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1. Write and balance the following reactions: (14 points)

   a. Calcium iodide is formed from its elements

   b. Molybdenum(III) selenide decomposes to its elements

   c. Combustion of butane, C_4H_{10}.

   d. Gallium reacts with a solution of zinc(II) nitrate.

   e. A bright white precipitate forms when solutions of silver(I) nitrate and potassium iodide react.

   f. Sodium hydroxide neutralizes hydrochloric acid.

2. Classify each of the above reactions: (1 point each)

   a.

   b.

   c.

   d.

   e.

   f.

CH 151
Sample Quiz #3 Name: ____ Lab Section: _______
Answers

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1. Write and balance the following reactions: (14 points)

a. Calcium iodide is formed from its elements **$Ca + I_2 \rightarrow CaI_2$**

b. Molybdenum(III) selenide decomposes to its elements **$Mo_2Se_{3(s)} \rightarrow 2\ Mo + 3\ Se$**

c. Combustion of butane, C_4H_{10}. **$2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)}$**

d. Gallium reacts with a solution of zinc(II) nitrate. **$2\ Ga + 3\ Zn(NO_3)_2 \rightarrow 2\ Ga(NO_3)_3 + 3\ Zn$**

e. A bright white precipitate forms when solutions of silver(I) nitrate and potassium iodide react.
$AgNO_{3(aq)} + KI_{(aq)} \rightarrow KNO_{3(aq)} + AgI_{(s)}$

f. Sodium hydroxide neutralizes hydrochloric acid. **$NaOH_{(aq)} + HCl_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$**

2. Classify each of the above reactions: (1 point each)

a. **combination**

b. **decomposition**

c. **combustion** *or* **burning**

d. **single replacement**

e. **precipitation**

f. **acid-base** *or* **neutralization**

CH 151 Sample Quiz #4 Name: ______________________________

Be sure to show all work, use the correct number of significant figures, circle final answers and use correct units in all problems.

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1. Draw the Lewis structure for water (H_2O). Describe the electron pair geometry (EPG), molecular geometry (MG), bond angles and polarity for water. (5 points)

2. Give electron configurations for the following atoms and ions (5 points)

Mg

Ga

Sc^{1+}

O^{2-}

Sr

3. Which **neutral atom** has the following electron configuration? Write the name and the symbol for the atom. (5 points)

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

$1s^2\ 2s^2\ 2p^2$

$1s^2\ 2s^2\ 2p^6$

$[Xe]\ 6s^2$

$[Rn]\ 7s^1$

4. Answer the following questions. (5 points)

What is the n value in 4p?

What is the ℓ value in 3d?

How many unpaired electrons are found in neutral atoms of N?

Is neutral magnesium paramagnetic or diamagnetic?

Is Mg^{2+} paramagnetic or diamagnetic?

CH 151 Sample Quiz #4   Name: ____

Answers

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1. Draw the Lewis structure for water (H_2O). Describe the electron pair geometry (EPG), molecular geometry (MG), bond angles and polarity for water. (5 points)

Water is tetrahedral (EPG), bent (MG), 109° and polar.

2. Give electron configurations for the following atoms and ions (5 points)

Mg	**$1s^2\ 2s^2\ 2p^6\ 3s^2$**
Ga	**$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^1$**
Sc^{1+}	**$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1$**
O^{2-}	**$1s^2\ 2s^2\ 2p^6$** *or* **[Ne]**
Sr	**$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2$** *or* **[Kr] $5s^2$**

3. Which **neutral atom** has the following electron configuration? Write the name and the symbol for the atom. (5 points)

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$	**Sulfur, S**
$1s^2\ 2s^2\ 2p^2$	**carbon, C**
$1s^2\ 2s^2\ 2p^6$	**Neon, Ne**
[Xe] $6s^2$	**Barium, Ba**
[Rn] $7s^1$	**Francium, Fr**

4. Answer the following questions. (5 points)

What is the n value in 4p?	**four (4)**
What is the ℓ value in 3d?	**two (2)**
How many unpaired electrons are found in neutral atoms of N?	**three (3)**
Is neutral magnesium paramagnetic or diamagnetic?	**diamagnetic**
Is Mg^{2+} paramagnetic or diamagnetic?	**diamagnetic**

CH 151 Midterm Exam Cover Sheet

Sample Exam

Name: ____

This sample exam consists of four (4) double-sided pages (including this sheet) with twenty-five (25) multiple choice questions, six (6) short answer questions, and one (1) five point extra credit question.

Point values are summarized on the next page.

A periodic table and scratch paper are available for you to use on this exam.

Before you start:

- Verify that you have all four (4) double-sided pages
- Write your name in the space above

At the conclusion of the exam:

- Sign the integrity statement below. **Failing to sign the integrity statement on this exam imparts an immediate grade of zero.**
- Ensure that all multiple choice answers are clearly marked
- Turn in the exam, the periodic table and all scratch paper used

---

Integrity statement:

I have neither given nor received aid on this exam.

____

Your signature

CH 151 Midterm Exam Point Distribution Sheet

Sample Exam

Multiple choice questions:

________ X *4 points per question* = _________ points

number of multiple choice questions correct

Short answer questions and extra credit:

_________ points

Total points on this exam: _________ points

Grade	***Percentage***	***Points on This Exam***
A	90% - 100%	117 - 130
B	80% - 89%	104 - 116
C	65% - 79%	84 - 103
D	50% - 64%	65 - 83
F	0% - 49%	0 - 64

CH 151 Sample Midterm Exam Name: ____

Part I: Multiple Choice Questions (100 Points) There is *only* one best answer for each question.

---

1. There are _____ ng in a pg. ($n = 10^{-9}$, $p = 10^{-12}$)

   a. 0.001
   b. 1000
   c. 0.01
   d. 100
   e. 10

2. Express the temperature 422.35 K in degrees Celsius.

   a. 792.23 °C
   b. 149.20 °C
   c. 692.50 °C
   d. 50.89 °C
   e. 22.78 °C

3. Which group in the periodic table contains only nonmetals?

   a. IA
   b. IIA
   c. VA
   d. VIIB
   e. VIIIA

4. The recommended adult dose of Elixophyllin®, a drug used to treat asthma, is 6.00 mg/kg of body mass. Calculate the dose in milligrams for a 115-lb person. 1 lb = 453.59 g.

   a. 24
   b. 1,521
   c. 1.5
   d. 313
   e. 3.1×10^5

5. Convert $5.01*10^3$ cm to km, m and mm

   a. $5.01*10^{-2}$ km, $5.01*10^1$ m, $5.01*10^4$ mm
   b. $5.01*10^{-2}$ km, $5.01*10^1$ m, $5.01*10^3$ mm
   c. $5.01*10^{-2}$ km, $5.01*10^5$ m, $5.01*10^8$ mm
   d. $5.01*10^4$ km, $5.01*10^1$ m, $5.01*10^{-2}$ mm
   e. $5.01*10^8$ km, $5.01*10^5$ m, $5.01*10^2$ mm

6. Which of the numbers has the *most* significant figures?

   a. $32,769,100*10^{-6}$ pg
   b. $12.19*10^{-3}$ g
   c. 9,241,000 J
   d. 0.00163 s
   e. 1,200,000.00 kWh

7. Elements in Group 7A are known as the

   a. alkali metals
   b. chalcogens
   c. alkaline earth metals
   d. halogens
   e. noble gases

8. Calcium forms an ion with a charge of

   a. +2
   b. +1
   c. -1
   d. -2
   e. unknown; it is a variable charge metal

9. Which of the following is a chemical property?

   a. Combustibility
   b. Boiling Point
   c. Density
   d. Melting Point
   e. Index of refraction

10. Which of the following is *true*?

    a. Two objects, both having positive charges, repel each other
    b. Two objects having opposite charges attract each other
    c. Electrostatic forces are responsible for the energy absorbed or released in chemical changes
    d. The number of neutrons in an atom of an element is variable depending on the isotope
    e. All of the above are true

11. Which of the following symbol/name pairs are correctly matched?

    a. Fl, Fluorine
    b. Ca, Carbon
    c. S, Silicon
    d. Ir, Iron
    e. Na, Sodium

12. Isobars of an element have similar

    a. protons
    b. neutrons
    c. electrons
    d. atomic numbers
    e. mass numbers

13. Which of the following masses is closest to the mass of one atomic mass unit (amu)?

    a. 12 g
    b. 1.66 g
    c. 1 g
    d. $^{1}/_{12}$ g
    e. 10^{-24} g

14. Which of the following is correct for the third period element in Group 4A?

	Z	**Chemical Symbol**	**Atomic Mass**
a.	31	Ga	69.72
b.	69.72	Ga	31
c.	14	Si	28.09
d.	28.09	Si	14
e.	21	Sc	44.96

15. Which of the following is correct?

    a. The element H is in both the first period and the seventh period
    b. The element Na is in Group 2A
    c. The element Ge is in the fourth period and Group 4A
    d. The element Cr is in the third period and Group 6B
    e. More than one of the statements above are correct

16. Which of the following name/formula pairs is correct?

    a. phosphoric acid, H_3PO_3
    b. sulfate ion, SO_3^{2-}
    c. bromate ion, BrO_3^{-1}
    d. hydrochlorous acid, HCl
    e. carbonate ion, CO_3^{-1}

17. What is the name of $Cu(ClO_3)_2 \cdot 2\ H_2O$?

    a. copper chlorate terthydrate
    b. copper(II) chlorate dihydrate
    c. copper chlorate terhydrate
    d. copper(II) chlorate terhydrate
    e. copper chlorate trihydrate

18. Which of the following is the correct name for the ammonium ion?

    a. NH_4
    b. NH_4^+
    c. NH_3^+
    d. NH_3
    e. NH_2^{-1}

19. What are the formulas of the compounds calcium periodate and potassium nitrate?

    a. $Ca(IO_4)_2$, KNO_2
    b. $Ca(IO_3)_2$, KNO_2
    c. $Ca(IO_4)_2$, KNO_3
    d. $Ca(IO_3)_2$, KNO_3
    e. $CaIO_4$, KNO_3

20. Identify the element below which does *not* form stable diatomic molecules:

    a. nitrogen
    b. hydrogen
    c. chlorine
    d. bromine
    e. carbon

21. How many molecules are in 0.105 mol of N_2H_4?

    a. $6.32*10^{22}$
    b. $5.73*10^{2\backslash 4}$
    c. $1.74*10^{-25}$
    d. $1.58*10^{-23}$
    e. 1.79

22. Calculate the molar mass of gallium carbonate

    a. 129.7 g/mol
    b. 154.3 g/mol
    c. 189.7 g/mol
    d. 319.5 g/mol
    e. 334.6 g/mol

23. Calculate the percent composition of gallium selenide.

    a. 37.1% Ga, 62.9% Se
    b. 42.3% Ga, 57.7% Se
    c. 44.1% Ga, 55.9% Se
    d. 46.7% Ga, 53.3% Se
    e. 50.0% Ga, 50.0% Se

24. From the following, pick the compound that could be an empirical formula:

    a. C_4H_8
    b. NH_3
    c. Al_2Br_6
    d. N_2O_4
    e. more than one of the above could be an empirical formula

25. How many grams of oxygen are in 8.50 g of potassium sulfite, K_2SO_3?

    a. 2.12 g
    b. 2.58 g
    c. 4.25 g
    d. 4.53 g
    e. 16.0 g

Part II: Short Answer / Calculation, 30 points total. *Show all work!*

1. A new compound called Chemane is composed of 40.00% C, 6.72% H, and the remainder oxygen. Calculate the empirical formula of Chemane. (8 points)

2. If the molar mass of Chemane in problem #1, above, is found to be 180.18 g/mol, calculate the molecular formula of Chemane. (6 points)

3. Provide the appropriate chemical formula or name to the following. Use acid names if appropriate. (1 point each)

phosphorus tribromide

SCl_4

sodium iodate

$Fe(ClO_2)_5$

calcium iodide

chromium(III) nitrate

$(NH_4)_2SO_4$

potassium phosphide

$HNO_3(aq)$

$Ca(OH)_2$

4. Find the mass of 115.7 cm^3 benzene in pounds. (density = 0.779 g/mL, 454 g = 1 pound) (4 points)

5. What is the **formula** and **molar mass** of calcium nitrate? (4 points)

6. Convert 4.2 K to °C and °F. (3 points)

CH 151 Sample Exam
Exam I Name: ____ Lab Section: ______
Answers

Part I: Multiple Choice Questions

1. A
2. B
3. E
4. D
5. A
6. E

7. D
8. A
9. A
10. E
11. E
12. E
13. E

14. C
15. C
16. C
17. B
18. B
19. C
20. E

21. A
22. D
23. A
24. B
25. B

Part II: Short Answer / Calculation.

1. CH_2O
2. $C_6H_{12}O_6$
3. *Names/formulas:*
    PBr_3
    sulfur tetrachloride
    $NaIO_3$
    iron(V) chlorite
    CaI_2
    $Cr(NO_3)_3$
    ammonium sulfate
    K_3P
    nitric acid
    calcium hydroxide
4. 0.199 lbs
5. $Ca(NO_3)_2$, 164.09 g/mol
6. -269.0 °C, -452.1 °F