# Chemistry 100: *The Complete Notes*

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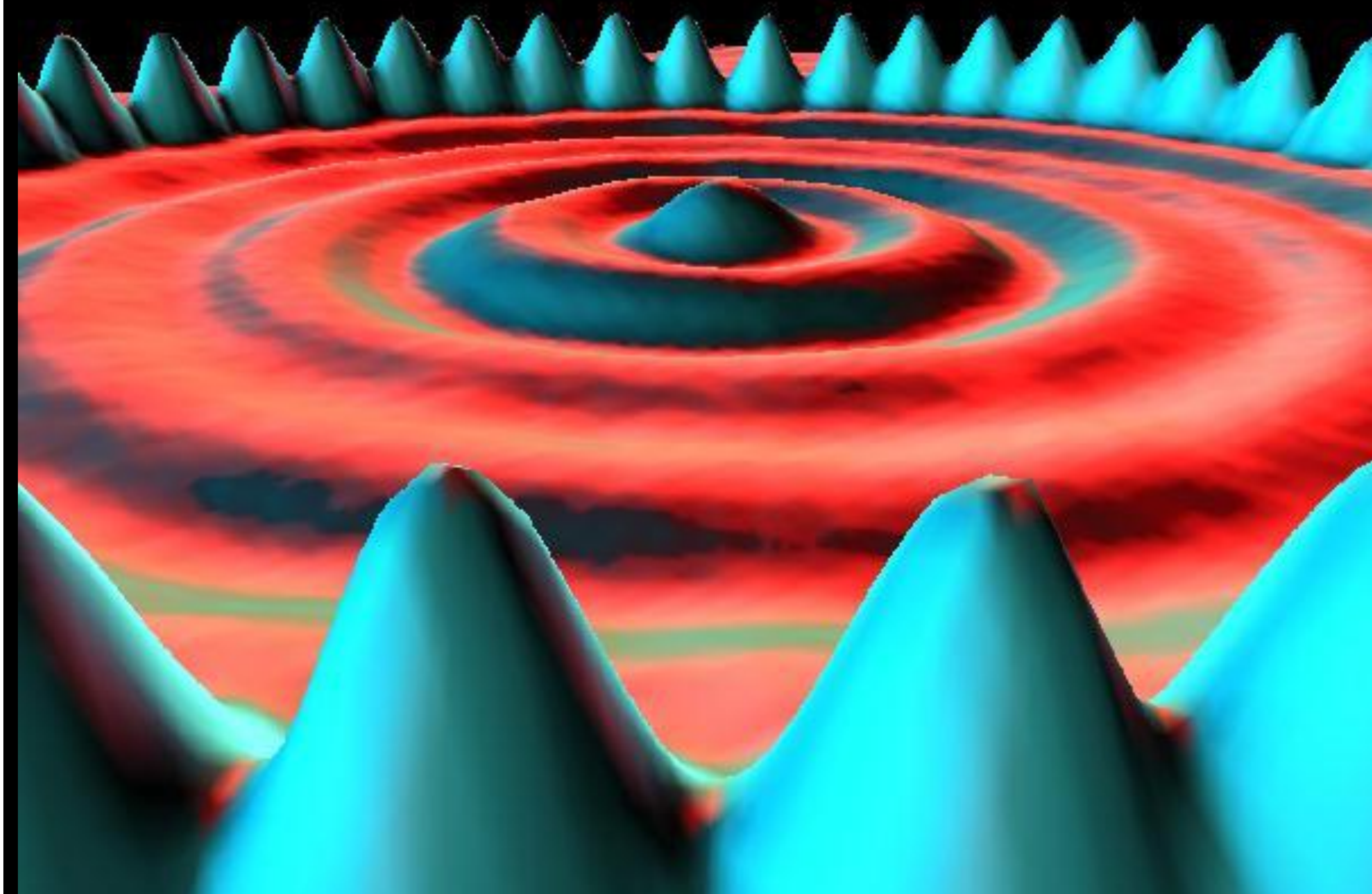


# Notes

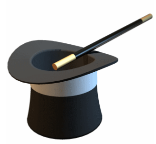
# Contents



**See the Course Website (http://ww3.jjc.edu/staff/pmills) for specific test dates and other important information**

# Legend

**You will often find specific icons embedded within the notes. These respective symbols alert the student to the following:**

| | |
|---|---|
|  | **Represents a *key* fact or other piece of information, such as the definitions of an element and a compound.** |
|  | **Represents a useful *trick* the student will likely find useful, such as an 'EZ' way to convert between grams and moles for a substance** |
|  | **Alerts the student to an important relationship between *micro* and *macro* scale properties or phenomena with respect to the material under discussion** |
| * | **Such material provides a link to interesting (*briefly* discussed) supplemental material, often beyond the scope of the course syllabus** |



**Cover Art**: The 'Quantum Coral' STM image

# Why Chemistry?

"What's my motivation?"

Why are you sitting in this class? In other words, why chemistry?

Task: Write down as many reasons as you can that explain why *you* are taking this class:
(We will also justify responses relating to 3rd party requirements during the session)

Professional programs that benefit directly from a background in chemistry

1. Nursing and allied health (pre-pharm., pre-med., pre-dentistry)

Example: Chlorothiazide (Diuril) is ordered b.i.d. for a infant weighing 6.5 kg. It is supplied in elixir form 100 mg/tsp. The recommended dosage for Diuril is 25 mg/kg/day. How many cc's should the nurse give to the child for each dose?

A. 6.15 cc.
B. 8.13 cc.
C. 4.06 cc.
D. 0.81 cc.

2. Engineering (mechanical, civil, chemical, electrical)

<u>Example</u>: Your company decides to import child safety seats manufactured in Asia. Unfortunately, the safety guidelines for the seats are quoted in 'metric' units. The label reads: "Do not exceed a 150 N load" and *you* must use this information to determine the maximum weight a child must not exceed in order to be protected during a collision at 55 mph. Can you do it? A child's life, not to mention the financial future of your employer, may depend on your ability to solve questions such as this.

3. Everyday / Real life situations

<u>Example</u>: It is time to re-carpet your 12 ft x 24 ft. family room. You visit a few carpet stores and select a brand that costs $ 20.50 per square meter. The sales person quotes you a total price of $749 – is this price fair, or have *you* just been taken advantage of?

** We will return to and solve each of these three problems at some point during the course

<u>Discussion</u>:

What do all three of the above examples have in common?

Which professions (or professionals) utilize such skills most commonly?

<u>Hint</u>, "I pretend to be one on occasion"

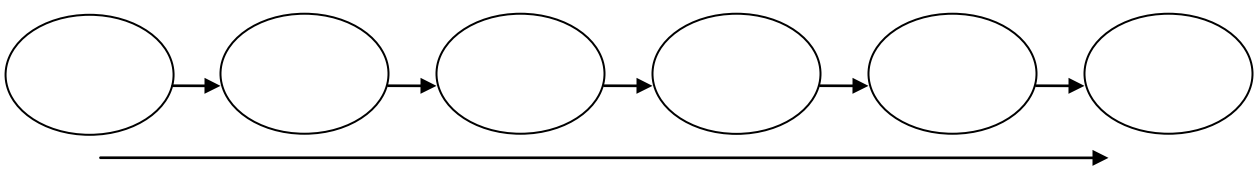
# The "Cognitive Elite"

Discussion: What do you think the phrase "cognitive elite" actually means?

Data from 'The Emergence of a Cognitive Elite' (Chapters 1 and 2 of *The Bell Curve*).

- People with IQ's of > 120 (the top 10%) preferentially enter the 10 or so 'High IQ professions' discussed above.
- Developing good cognitive skills is essential to entering and being successful within the 'High IQ' ***and related*** professions. **We are the first link in the chain**

Example: 'Medical chain'



*Increased Problem Solving Ability*

Take home message: People with good cognitive / problem solving skills preferentially find employment within fields *of their choosing* that are financially rewarding and/or intellectually satisfying.

A question of some importance: How can one's cognitive skills be improved?

Answer(s):

# The Role of Chemistry as a Prerequisite Course

Key facts and results:

**Fact: The problem solving skills routinely utilized in the 'high IQ' *and related* professions (such as nursing, business management, accounting, etc.) are introduced, learnt and mastered during physical science courses.**

Result: Professional programs and subsequent employers *insist* that their candidates have a background in one of the physical sciences – both for specific (allied health, engineering) and general (your family room carpet) reasons.

**Fact: Study within any of the 'high IQ fields' will increase cognitive skills, but *only* the physical sciences do so via the study of *fundamental*, everyday phenomena so are of broad relevance and interest** (we all interact with and benefit from the manipulation of matter on a daily basis after all).

Result: Chemistry (and physics) may be considered to be the 'gatekeepers' of cognitive learning – **chemistry in particular introduces, develops and subsequently equips students with cognitive skills necessary to succeed in their chosen careers**

Take home message: While the *direct* relevance of chemistry to your chosen course of study may at times seem tenuous, ***remember*** that the cognitive skills developed during such programs of study are of significant importance to your professional development and employability. In essence, ***this is why you are here***.

# How Chemistry is Perceived & Skills Needed to Succeed in Chemistry

<u>How Chemistry is Perceived</u>:

<u>Discussion</u>: How did your friends and family respond when you told them you were taking a chemistry course this semester??

[“Frank” slide]

<u>Study Skills Needed to Succeed in Chemistry</u>:

<u>Fact</u>: **As discussed above, chemistry is *all about* the student developing and learning to apply problem solving skills - your study habits should reflect this**. *Do NOT fall in to the trap of believing you can learn chemistry simply by memorizing the information from your text* – you must practice applying this information, *not* just be familiar with it.

<u>Result</u>: Successful chemistry students typically spend most of their independent study time *working* assigned problems, not just reading about them. ***To learn chemistry you must do chemistry*** is a truism worth remembering. An analogy would be this: you read all the books out there on the subject of golf, but don’t get round to swinging a club – what do you think happens when you tee off for the first time?

<u>Fact</u>: **Chemistry relies on a cumulative method of learning**, i.e. theories learnt from week 1 onwards will be repeatedly applied all the way through the course. Thus, **it is important that the student does not let any ‘gaps’ in their knowledge develop**. This fact exemplifies the differences in philosophy between the sciences and arts, as art courses are often more modular in nature. Example: I overhead a student tell another: “Yeah, I blew off reading the first book in my English class, but read the second one and got a ‘B’”. This method of study is not recommended in chemistry!

<u>Analogy</u>: Building a tower

Result: **Successful chemistry students typically have exemplary attendance records**. In some cases they may not be the 'best' students, but guarantee themselves a better grade than more capable students, who in turn typically may miss as few as one or two lecture sessions (this is especially true with regard to 3 hr. class sessions).

Pictorial analogy of attendance vs cumulative knowledge

'I missed a lab'

'I missed a lecture'

'I missed a couple of lectures'

Don't 'Swiss cheese' or 'torpedo' your chances of passing the course because of missed work!

Take home message: **Simply by attending class regularly and completing the HWK assignments you essentially guarantee yourself a passing grade for the course**, while, due to the nature of the material, deviating from this approach may ensure the opposite

# What is chemistry? What do Chemists do?

| | | | |
|---|---|---|---|
| <u>Reading</u>: | Ch 1. (all) | <u>Homework</u>: | 1.2 questions 5, 6<br>1.5 questions 14, 16* |

* = 'important' homework question

<u>Task</u>: In your own words describe what *you* consider chemistry to be, plus make a list of what *you* think the job of a chemist is:

<u>What is chemistry</u>?

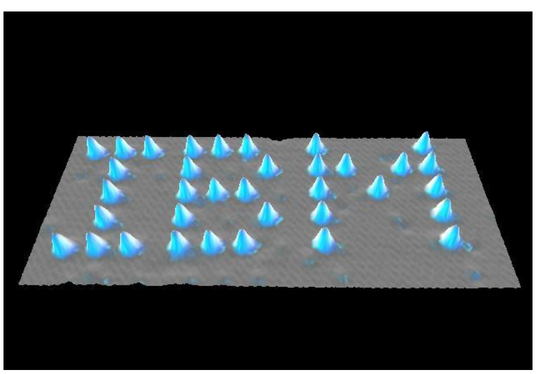
<u>"Official" definition of what chemistry is</u>:

Key words:

Matter: “Stuff” – **anything with mass and volume**. Can you think of anything without mass or volume?

The States of Matter – what are they? Are there any more?

What are the basic building blocks of all matter, be it a diamond, a tree or the air around us?



‘High Tech’ science (STM or AFM, top left) is often based on simple ideas (gramophone, top right). Click logo for ‘flyby’.

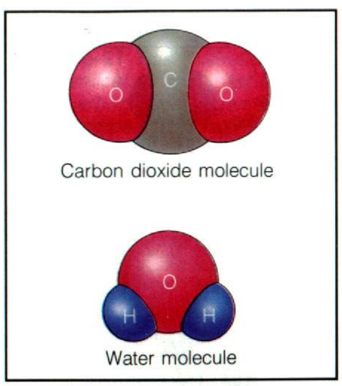
**All Matter is made from Atoms** – the *chemical formula* of the matter tells you the number and type(s) of the atoms 'inside'.


'Jeopardy' Example:

Answer: '$H_2O$ is the chemical formula of this common form of matter'

Question:

Examples | Chemical Formula




Important

**Atoms and molecules are MICROSCOPIC particles (they are *very, very* small), you cannot see them with your eye!**

**A drop of water is a MACROSCOPIC particle (because you can see it, hold it in your hand etc.) – it contains *many, many, many* individual molecules of water!**

What do chemists do?

"Official" definition of what chemists do:

Chemistry in action: Explaining what happens on your BBQ grill.

The burning of a charcoal brick on your backyard grill (MACRO) explained in terms of a *balanced chemical equation* (MICRO)

**ANY large (MACRO) scale chemical process can be described using a MICRO scale chemical equation featuring individual atoms and/or molecules**

Cartoon representation of the reaction of the pertinent atoms and molecules

The Chemists' description – a balanced chemical equation. This process is repeated many billions of times (MICRO) for the burning of a charcoal briquette (MACRO)

# Using Large and Small Numbers – Scientific Notation

| | |
|---|---|
| Reading: Ch. 2 sections 1 - 2 | Homework: 2.1, questions 2, 6, 8,10*,14* |

* = 'important' homework question

## Large Numbers

Fact: Chemical problem solving *most often* involves using either very large or very small numbers (e.g. counting the number of molecules in a drop of water, or quoting the mass of the water drop in kilograms)

Recall: How many individual $H_2O$ (l) molecules are there in a drop of water. Write this amount as a regular number:

Number $H_2O$ (l) molecules in 1 drop water = __________________________________

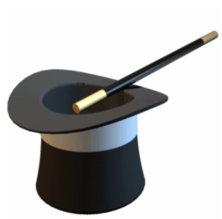
Problem: How do we represent and manipulate such numbers in an 'easier' way?

Answer:

Overview Example: Consider the statement "*eight million people live in London*". How can this quantity be *best* expressed numerically?

'Everyday':

‘<u>Better</u>’:



**Just move the decimal point to the left until you get a single digit with decimals.** The *power of ten* is the number of places the decimal point moved. <u>Example</u>:

$$3000 = 3 \times 10^{(\text{number decimal places to } \textit{left} \text{ moved})} = 3 \times 10^3$$

<u>Examples</u>: Write the following quantities using *regular numbers* and *powers of 10 (scientific notation).* Try to do this without a calculator at first, then see the below tip for how to do this with your calculator’s SCI button

| **Quantity** | **‘Regular’ quantity** | **‘Power of ten’ quantity (SCI)** |
|---|---|---|
| One hundred miles | | |
| One thousand students | | |
| Five million people | | |
| Twenty million dollars | | |
| Five and a half billion people | | |

TIP: Scientific notation (SCI) is different than the powers of 10 used in engineering (ENG). When converting to SCI powers of 10 from a 'real' number press the $\boxed{\text{SCI}}$ button on your calculator, or put it in SCI mode and press the $\boxed{=}$ key.

Example: Enter the number twelve million (12000000) into your calculator. Press the $\boxed{\text{SCI}}$ key, and then repeat with the $\boxed{\text{ENG}}$ key. What numbers do you get?

$\boxed{\text{SCI}}$: $\boxed{\text{ENG}}$:

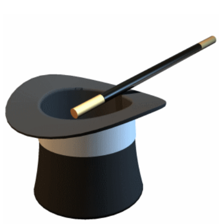
Wrap up: quote the number of $H_2O$ molecules in 1 drop water using SCI notation:

1,000,000,000,000,000,000,000 molecules = _______________ molecules

**REMEMBER: In chemistry we ALWAYS use scientific notation (SCI) for expressing large (>100) or small (<0.1) numbers.**

**Small Numbers**

Question: How can very small numbers be expressed in SCI notation?



**Just move the decimal point to the right until you get a single digit with decimals.** The ***negative*** *power of ten* is the number of places the decimal point moved. Example:

$$0.00125 = 1.25 \times 10^{-\text{(number decimal places to } \textit{right} \text{ moved)}}$$

= _____________________

Examples: Convert the following *regular numbered quantities* to *powers of 10 (scientific notation).* Try to do this without a calculator at first, then check with your calculator.

| **'Regular' number (quantity)** | **'Power of ten' number (SCI) (quantity)** |
|---|---|
| 0.00015 grams | |
| 0.125 % | |
| 0.0458 mL | |

Review: You now know how to convert large or small 'regular' numbers into SCI notation either on paper or using your calculator.

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**Entering and Manipulating Large and Small Numbers: (using the EE or EXP button)**

Enter the following SCI notation **numbers** into your calculator **- *try*** to use EE or EXP key, then press the = (in 'FLO' mode) to obtain the 'real' number equivalent:

| **'Power of ten' number (SCI)** | **Regular number** |
|---|---|
| $5 \times 10^{-1}$ | |
| $1.5 \times 10^{3}$ | |
| $3.56\ 10^{-3}$ | |

**Did you get the answers right?** PLEASE LET ME KNOW IF YOU NEED ASSISTACE WITH THIS EXERCISE

<u>Task</u>: Use your calculator to solve the following math problem – use the $\boxed{\text{EE}}$ or $\boxed{\text{EXP}}$ to enter the **numbers** in SCI notation. What happens if you try the same math using other keys, such as $\boxed{10^x}$ or $\boxed{\wedge}$?

$3 \times 10^7 \div 6 \times 10^3 =$ ____________________

What answer did you get?  What problems were encountered?

Using ***only*** the $\boxed{\text{EE}}$ or $\boxed{\text{EXP}}$ keys to express powers of 10 values, calculate the following. PLEASE LET ME KNOW IF YOU NEED ASSISTACE WITH THIS EXERCISE:

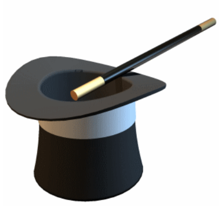
1. $(4 \times 10^{-9})(2 \times 10^4) =$ ________________________
2. $4 \times 10^{-9} \div 3 \times 10^4 =$ ______________________
3. See class examples

## Making things even simpler – S.I. Prefixes

**Certain powers of 10 can be replaced by a *symbol* known as a *decimal (or S.I.) prefix***

Use the slide shown or data from your book to complete the following table:

| Prefix | Symbol | Meaning | Power of 10 |
|---|---|---|---|
| Giga | G | 1000000000 (billion) | |
| Mega | M | 1000000 (million) | $1 \times 10^{6}$ |
| | k | 1000 (thousand) | |
| Deci | | 0.1 (ten*th*) | |
| | c | | |
| Milli | | | |
| | μ | | $1 \times 10^{-6}$ |
| Nano | n | | |



**For decimal (S.I.) prefixes, just swap the appropriate "x $10^{n}$" part of the number for the equivalent prefix's symbol**. <u>Example</u>:

**$1.25 \times 10^{-3}$ g = 1.25 mg (milligrams)**

Task: Convert the following quantities to SCI notation and decimal prefix notation:

| Quantity | With SCI notation | With Decimal Prefix |
|---|---|---|
| 0.0000020 meters | | |
| 0.0015 grams | | |
| 3,000 dollars | | |
| 12 million people | | |

Task: Now convert the following quantities to SCI notation and ‘regular’ numbers:

| Quantity | With SCI notation | As a ‘real’ number (quantity) |
|---|---|---|
| 2.5 mm | | |
| 5.2 km | | |
| 50 MW | | |
| 12 μm (microns) | | |

Discussion: Make a list of as many ‘everyday’ quantities as possible that use decimal prefixes (or similar related expressions):

# Units and Significant figures

| | |
|---|---|
| Reading: Ch. 2 sections 3 - 5 | Homework: 2.2, questions 15,16, 18,<br>2.5, questions 38, 39, 42*, 44* |

* = ‘important’ homework question

## Common Units

Discussion: List some common units of measurement we use on a daily basis. How did these units originate?

| Familiar Unit | Quantity measured |
|---|---|
| | Mass |

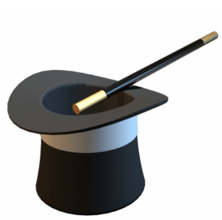
Question: What are the ‘metric’ (S.I.) versions of the everyday units listed above?

| Quantity measured | Fundamental S.I. Unit (**base** unit) | Symbol |
|---|---|---|

Notes: SI base units are used to determine derived S.I. units, as discussed below. **Some S.I. base units feature a *decimal prefix* – which one(s)?**

Discussion: Why do scientists prefer the S.I. system?

## Derived S.I. Units



**Insert appropriate S.I. base units into an equation that defines the respective derived S.I. unit.** Example:

Area = length x length = m x m = $m^2$

$\Rightarrow$ the *derived* S.I. unit for area is $m^2$

Determine derived S.I. units for the following quantities

| Quantity measured | Math involving S.I. base units | Derived S.I. unit |
|---|---|---|
| Volume | | |
| Velocity (speed) | | |
| Density | | |
| Force* | | |
| Energy* | | |

*These are harder examples. To solve them start by inserting appropriate S.I. base units into an equation that defines the quantity sought.

Questions:

Is the S.I. unit of volume ($m^3$) reasonable for everyday applications? Why?

What unit of volume do chemists prefer? Why?

More detail on the chemist’s volume unit

## Significant Figures and Rounding Off

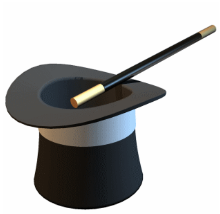
<u>Question</u>: What are significant figures?

<u>Task</u>: Measure the length of your pencil (or some other object) in cm using a standard ruler. To how many sig. figs can you determine this value?

| Object | Size of measures (cm) | Number sig. figs. |
|---|---|---|
| | | |
| | | |
| | | |

Let's figure out the rules for sig. figs. What is:

| | |
|---|---|
| 1.002 to | 3 sig. figs. |
| | 1 sig. fig. |
| 569.74 to | 3 sig. figs. |
| | 4 sig. figs. |
| | 1 sig. fig. |
| 0.00017 to | 1 sig. fig. |



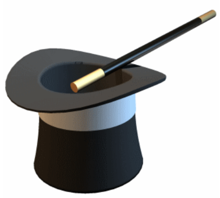
**Zeros *before* the first number are *NOT* counted as significant**

**Zeros *after* the first number *ARE* counted as significant**

**Round UP if the number after the last significant digit is > 5**

**Quote numbers in SCI notation if number sig. figs. < digits before decimal point.**

Multiplication and division **(99% of your work is either one and/or the other)**



**The result of any multiplication or division has the same number of sig. figs. as the measurement with the lowest number of sig. figs.** Example: A sample of lead has a mass of 2.105 g and a volume of 0.11 mL. What is the density of lead?

Answer:

Another example: What is the area (in $ft^2$) of a 12.5 ft x 24 ft room?

What common mistake was made in the determination of length here?

# Dimensional Analysis (Conversion Factors)

<u>Reading</u>: Ch. 2 sections 6 <u>Homework</u>: 2.6, questions 60, 64*, 68, 70

* = 'important' homework question

**Background**

We do simple conversions between different units on a daily basis. For example:

<u>Question</u>:

How many eggs are there in 1 dozen eggs? ________

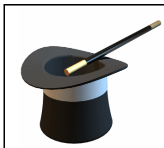
A statement such as this can be written as an *identity*

**1 dozen eggs = 12 eggs**

<u>Recall</u>: Is the above identity a measured or exact relationship? How would its use affect the number of significant figures used in any answer?

**Using Identities and Conversion Factors**

<u>Overview Example</u>: How many eggs are there in 42 dozen eggs?



**Use the appropriate identity to create a conversion factor. The conversion factor will transform the quantity into the desired form**.

<u>Math</u>:

42 dozen eggs x = _______________

**Conversion factors are simply identities written as fractions. Each conversion factor has two 'versions'**

<u>Task</u>: Complete the following table by transforming the stated identity into its two corresponding conversion factors. Also include at least three additional conversion factors that *you* have encountered.

| **Identity** | **Conversion factors** | | **Exact? (Y/N)** |
|---|---|---|---|
| 1 in = 2.54 cm | | | |
| 1 kg = 2.205 lb | | | |
| 1 m = 100 cm | | | |
| 1 ft = 12 inches | | | |
| | | | |
| | | | |
| | | | |
| | | | |
|  | | | |

Discussion:

How do you know which version of the conversion factor to use? Why?

For none exact identities and conversion factors, how many sig. figs are implied?

Example: Use the information from above to determine how many cm there are in 12.00 inches.

12.00 inches x = _______________

**The unit belonging to the quantity and the denominator of the conversion factor cancel to leave a final answer with the desired unit**

Generic Form:

Task: Complete the following conversions. See your text for appropriate conversion identities.

5.51 cm to meters

23.0 ounces to pounds

50.0 nm to meters

6.56 miles to km

45.7 inches to cm

220 pounds to kg

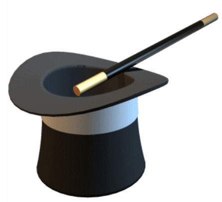
(you choose examples)

**Conversion Factor 'Chains'**

Question: How do you approach a problem like "Convert 55 cm into feet" – where there is no available single conversion factor?

Answer:

55 cm x x = ________________



**Link as many conversion factors as necessary together in order to crate a 'chain'. Each 'link' in the chain converts one unit to another and so on until the answer is reached**

Task: Complete the following 'chain' conversions. See your text for appropriate conversion identities.

1.68 m to inches

5.8 km to feet

4.00 ounces to grams

Question of the week: Remember that nursing question from week 1? Let's try it now….

Example: Chlorothiazide (Diuril) is ordered b.i.d. for a infant weighing 6.5 kg. It is supplied in elixir form 100 mg/tsp. The recommended dosage for Diuril is 25 mg/kg/day. How many cc's should the nurse give to the child for each dose?

A. 6.15 cc.
B. 8.13 cc.
C. 4.06 cc.
D. 0.81 cc.

'Medical' conversion factors

b.i.d.: 2 dose = 1 day
1 tsp. = 5.0 mL

## *"Conversions"*

The following questions were taken from your 1st practice midterm:

Complete the following conversions (include correct number of sig. figs.):

95.5 pounds to kg

ANS: 43.3 kg (3 sf)

1032 cm to meters

ANS: 10.32 m (4 sf)

12.5 miles to km

ANS: 20.0 km (3 sf)

-156 $^{o}$C to Kelvin
(see next handout)

ANS: 117 K

1300 Cal to kJ

ANS: 5439 kJ or $5.439 \times 10^6$ J (4 sf)

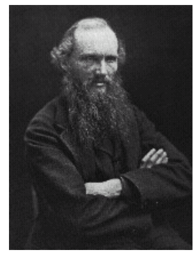
# Temperature and Density

| | | | |
|---|---|---|---|
| Reading: | Ch. 2 sections 7 - 8 | Homework: | 2.7, questions 72, 74, 76, 78*, 82*<br>2.8, questions 86, 90, 92*, 94*, 96, 100* |

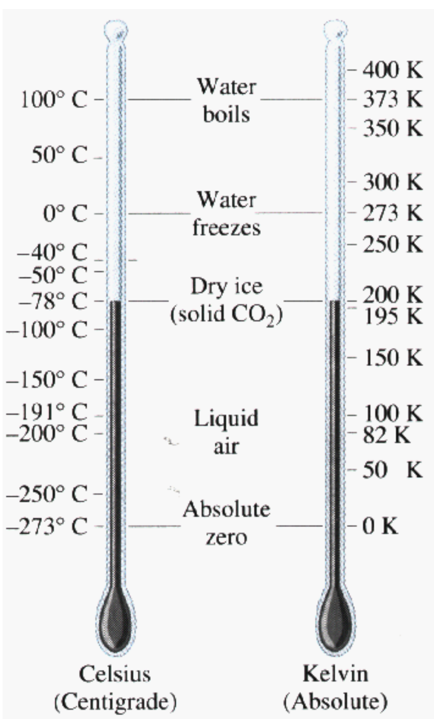
* = 'important' homework question

## Temperature

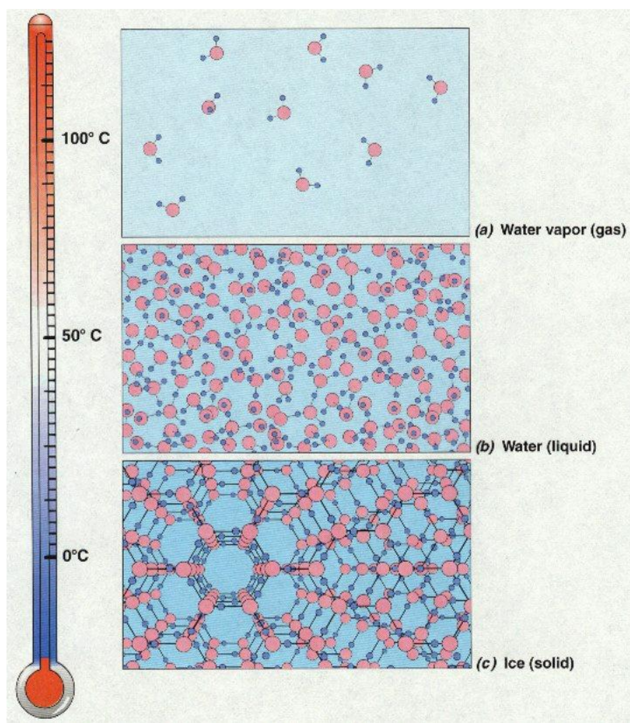
Background: There are three temperature scales in common use today. Can you name them?



How were the end points of the two 'metric' scales defined? In other words, what natural conditions define these respective temperature values?




The Centigrade and Kelvin Scales



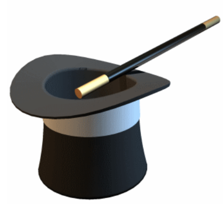

The Centigrade scale compared to the state of $H_2O$

Converting between Degrees Celsius and Kelvin

Task: By looking at the above graph, describe how the $^{o}$C and K scales are related. What do they have in common? What is different?

**1.**

**2.**



**Simply *add* 273.15 to ANY temp. quoted in $^{o}$C to obtain the equivalent K value**

**OR**

**Simply *subtract* 273.15 from ANY temp. quoted in K to obtain the equivalent $^{o}$C value**

Examples:

1. What is 50$^{o}$C in Kelvin?

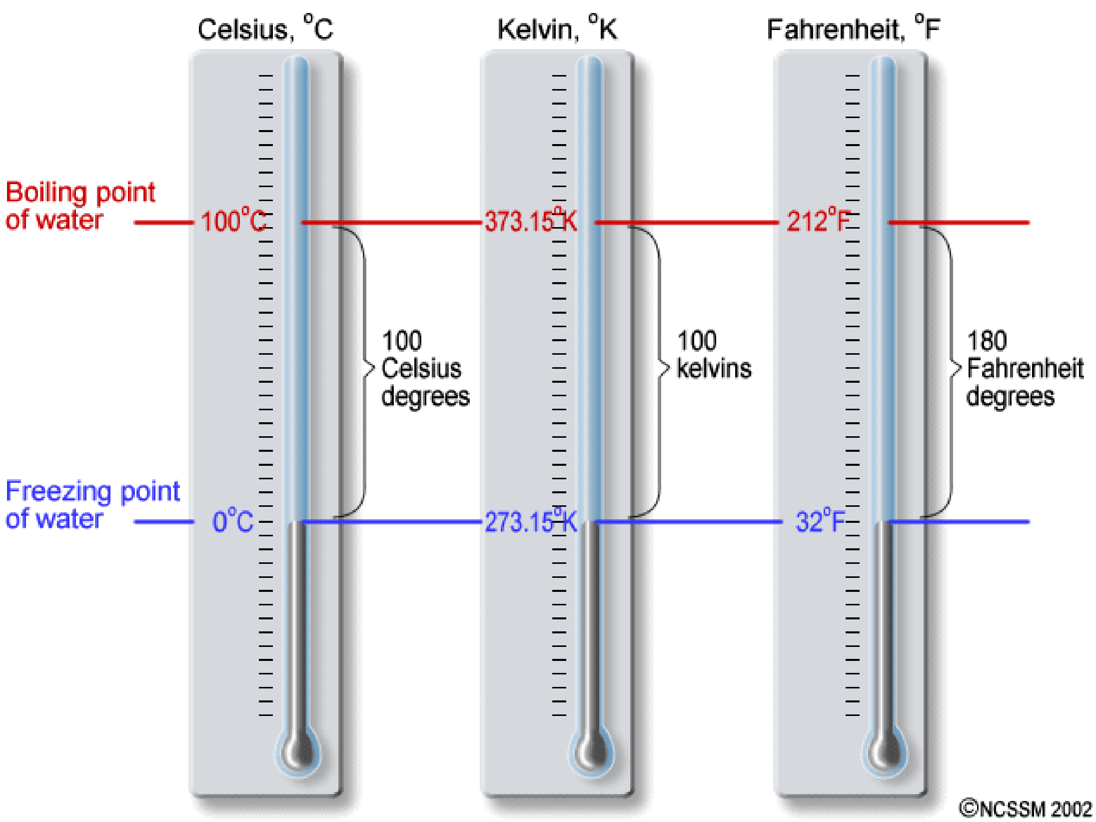
2. What is 200 K in Celsius?

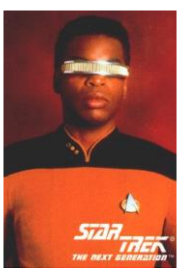
Comparing the Fahrenheit, Kelvin and Celsius Temperature Scales

Discussion: We saw that the end points for the °C scale corresponded to specific 'natural' temperatures – the same is true for the °F scale. What 'natural' temperatures do you think 0 °F and 100 °F correspond to in nature. How about 212 °F and 32 °F?

*"You want to put what, where?!.."*

Diagram: Fahrenheit, Celsius and Kelvin thermometers side by side.




Question: What is the obvious error in the above diagram?

Task: By looking at the previous diagram, or the slide provided, describe how the $^{o}$C and $^{o}$F scales are related. What do they have in common? What is different?

**The two basic differences between the $^{o}$C and $^{o}$F scales allow for equations relating them (conversion equations) to be constructed:**

For converting $^{o}$C to $^{o}$F:

For converting $^{o}$F to $^{o}$C:

Question: What is 90 $^{o}$F in $^{o}$C and in Kelvin?

Ask me about the *extra credit* temperature….

**Temperature Ranges**

Discussion: If something is boiling, is it necessarily 'hot'? If it is frozen, is it necessarily 'cold'?

Task: View and make brief notes on the 'temperature scale' slide. Think of the 'hottest' and 'coldest' things you come into contact with on a daily basis – where do they fit into the 'bigger picture'?

**Density**

<u>NOTE</u>: THE FOLLOWING IS A REVIEW OF THE MATERIAL YOU WILL LEARN DURING LAB #2.

<u>Review</u>: How was the property of density defined during a previous lecture?

**Density:**

<u>Where</u>: 'amount of matter' = ________________

<u>Discussion</u>: What is the S.I. unit of density? Is this a convenient unit?

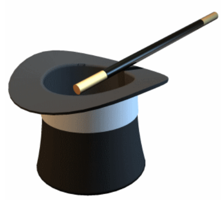
$\Rightarrow$ Density = ____________________________________

<u>Question</u>: What are the two 'convenient' *derived* S.I. units of density used by chemists?

## Density Math

Recall: Density is defined by a simple equation, which has three related forms:

| | | |
|---|---|---|
| 1. | 2. | 3. |



**If you have problems with cross multiplication, remember that 'pyramids' can also be used to solve density and other 3 variable equations:**

Example: 23.5 mL of a certain liquid weighs 35.062 g. What is the density of the liquid? What mass will 20mL of this liquid have?

# Density Applications

## Finding the Volume and / or Density of Solid Objects

| |
|---|
| NOTE: THE FOLLOWING IS A REVIEW OF THE MATERIAL YOU WILL LEARN / HAVE LEARNT DURING LAB #2. |

Irregular shaped objects

**Any Object will DISPLACE it's own volume of water when submerged**

Recall lab: Sketch the apparatus you used to measure the volume of the rubber stopper:

| 1. Before the stopper was added | 2. After the stopper was added |
|---|---|
| | |

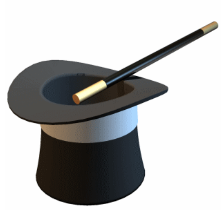
Example: A solid object weighing 15.250 g is submerged in water, during which time the water level rose from 50.0 mL to 60.2 mL. What is the density of the object?

Regular shaped objects

|  | **Regularly shaped objects (cubes, ‘bricks’, spheres, cylinders, cones….) have *equations* that define their volume.** |
|---|---|

Task: Sketch the following 3-D shapes and list the equations that define their volume (see your text book)

| Sketch of 3-D Shape | Volume equation |
|---|---|
| Cube | V = |
| ‘Brick’ | V = |
| Sphere | V = |
| Cylinder or disk | V = |

|  | **1. Find the volume of the object in question via the equation that defines its volume (be sure to use cm for all length dimensions).**<br><br>**2. Substitute the derived volume value in D = M/V to find the object’s density (recall that mass is measured in grams).** |
|---|---|

Recall: the radius of a circle equals half of it’s diameter (i.e. dia.= 2r)

Example: Dice used in Las Vegas weigh 2.65 g and have sides of length 1.2 cm. What is the density of a Las Vegas dice?

**Densities of common materials**

| Material | State (s), (l) or (g) | Density (g/cm$^3$) |
|---|---|---|
| Oxygen | | 0.00133 |
| Ethanol | | 0.785 |
| **Water** | | **1.000** |
| Iron | | 7.87 |
| Silver | | 10.5 |
| Lead | | 11.34 |
|  Mercury | | 13.6 |
| Gold | | 19.32 |

**“Will it Float?”**

The David Letterman Show on CBS often features a segment called ‘Will it Float’. Simply, Dave and Paul try to determine if an object, such as a refrigerator or 100 ft of insulation cable, will float when dropped into a large container of water.

Question: What physical property of a material will determine ‘if it will float’? What would be a more scientifically accurate (if less catchy) name for the ‘Will it float’ segment on Dave’s show?

Discussion: “Battleships and dating advice”

Task: Using the table supplied above, sketch a picture of what would happen if ~30 mL samples of ethanol, mercury and water, as well a silver dollar and a gold ring were added to a volumetric cylinder.

Question of the week (group work)

If a 200 mg piece of gold is hammered into a sheet measuring 2.4 ft by 1.0 ft, then what is the sheet's thickness in meters? If a gold atom is 0.26 nm wide, how many atoms thick is the sheet?

## *“The Wire” & “Sketch”*

The following questions were taken from your 1st practice midterm:

A copper (Cu) wire has a mass of 4.00 pounds and a diameter of 5.00 mm. **Determine the wire’s mass and in the units specified below. Include any appropriate decimal prefixes in your final answers**. Density of copper = 8.95 g/$cm^3$

<u>Mass of the wire in kg</u>:

<u>ANS</u>: 1.81 kg (3 sf)

<u>Volume of the wire in $cm^3$</u>:

<u>ANS</u>: 202 mL (3 sf)

Sketch a fully labeled diagram illustrating the appearance of a 100 mL cylinder after the following items have been added to it:

| Material | Density (g/$cm^3$) |
|---|---|
| 40 mL D.I. water | 1.000 |
| A medium sized silver ring | 10.50 |
| 40 mL liquid mercury | 13.6 |
| A small gold coin | 19.32 |
| 20 mL Olive oil | 0.756 |

<u>ANS</u>:

| | |
|---|---|
| <u>Top</u> | Olive Oil |
| | D.I. Water |
| | Silver ring |
| | Mercury (l) |
| <u>Bottom</u> | Gold coin |

# Matter

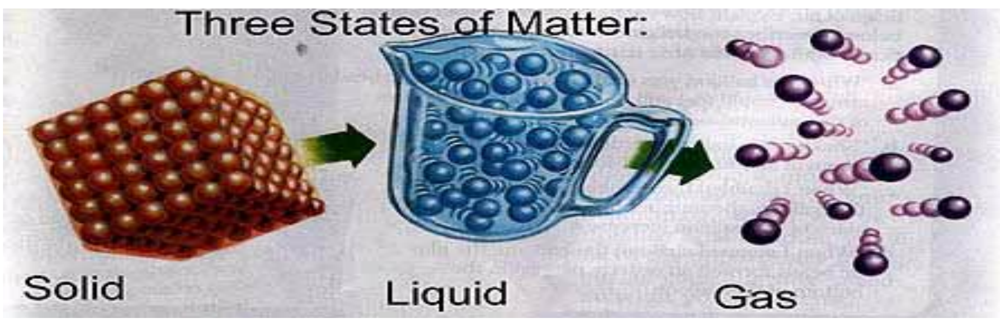
| Reading: | Ch 3 sections 1 - 5 | Homework: | 3.1, questions 2, 4, 6, 8*<br>3.2, questions 12, 16, 18*<br>3.3, questions 20, 24<br>3.4, questions 26, 28, 30*, 32*<br>3.5, questions 34, 36 |
|---|---|---|---|

* = 'important' homework question

Review: What is the ('MTV') definition of matter?

Recall: "Chemistry is the study of matter and its *properties*, the changes matter undergoes and the *energy* associated with those changes"

Recap: There are 3 stable states of matter – *solid* (s), *liquid* (l) and *gas* (g).




Specific physical properties define the 3 states of matter

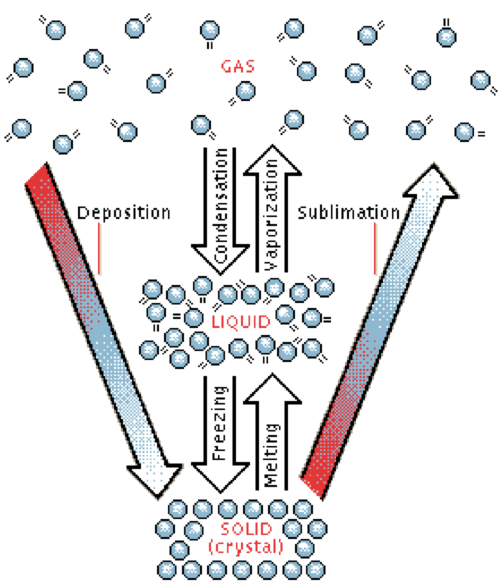
| State of Matter | Macroscopic Description (observation) | Microscopic Description (chemical model) |
|---|---|---|
| Solid | | |
| Liquid | | |
| Gas | | |

**The state matter is in depends on the strength of the forces (chemical bonds) between the individual microscopic particles within the matter**

Task: Rank the *intermolecular* forces present in steam, ice and water in order of increasing strength. Use the slide or above figure as a guide.

**Changing between the 3 states of matter (a physical property)**

Question: How do you convert $H_2O$ (s) (ice) $\rightarrow$ $H_2O$ (l) (water) and back again?




Notes

Question: What happens on the microscopic level during the above processes (recall previous slide)? ***How is this related to boiling and freezing points??***

**Physical and Chemical Properties – what's the difference?**


Analogy: We all posses 'as is' properties, or characteristics, that define us. For example, Dr. Mills is 5'11" and has green eyes.

**Physical Properties** As with people, each chemical also possesses a unique set of 'as is' (physical) properties that define it. For example, water is a clear, colorless, tasteless molecular material that has a fpt. of 0$^o$C and a bpt. of 100 $^o$C.

**Chemical Properties**, in contrast, are a function of *change* (usually associated with a chemical reaction). For example, Iron (Fe) reacts with oxygen gas to form rust:

$$4\ Fe\ (s)\ +\ 3\ O_2(g)\ \rightarrow\ 2\ Fe_2O_3\ (s)$$

Task: Identify the flowing as either chemical or physical properties

| Properties | Chemical or Physical |
|---|---|
| Diamond is the hardest known substance. | |
| Charcoal burns to make $CO_2$ (g) | |
| The statue of liberty turned 'green' | |
| Copper is a good conductor of electricity | |
| Sugar dissolves in water | |

*Think up two more chemical properties of your own - ***6 more physical properties to beat the record(!)***

**Elements and Compounds**

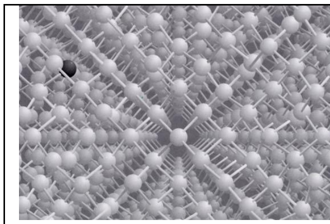
<u>Task</u>: State which of the following are *elements*, and which are *compounds*. When done, try to come up with a definition of what elements and compounds are.

| <u>Material</u> | <u>Chemical Formula</u> | <u>Element or Compound?</u> |
|---|---|---|
| Water | $H_2O$ (l) | |
| Oxygen gas | $O_2$ (g) | |
| Pure silver coin | Ag (s) | |
| Sugar crystals | $C_6H_{12}O_6$ (s) | |
| Carbon dioxide gas | $CO_2$ (g) | |
| | | |
| | | |
| | | |

**<u>Elements</u>:**

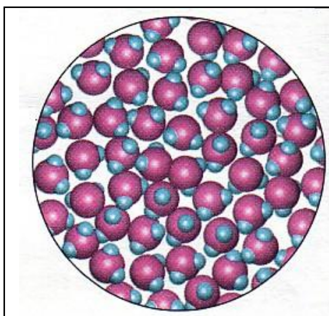
**<u>Compounds</u>:**

Note: Compounds and elements can have either *'giant'* or *molecular* structures:



'Giant': Repeating *lattice* of particles – usually strongly bound (high mpt.) solids.

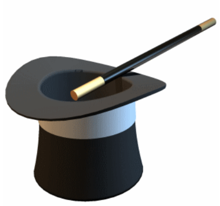
Examples: sand ($SiO_2$), diamond (C), table salt (NaCl)



Molecular: a collection of *independent* molecular units (molecules will be discussed in more detail later). Usually (low mpt) liquids or gasses at room temp.

Definition: ***Molecule*** **– a small, independent particle of matter made up from 2 or more atoms**

Examples: water ($H_2O$), carbon dioxide ($CO_2$), Nitrogen gas ($N_2$)

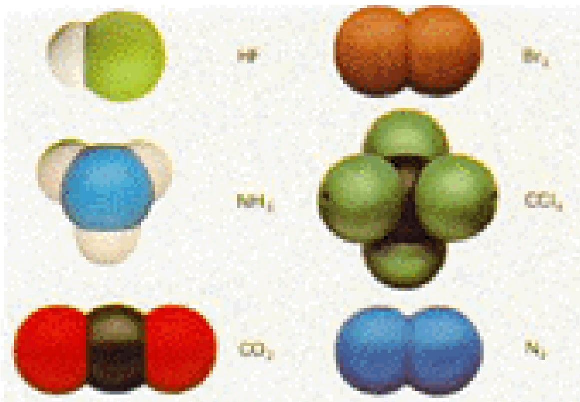


**Think of molecules like cars on the expressway – each car (molecule) is a separate, independent unit that contains a number of passengers (atoms). The cars (molecules) are free to move while the people (atoms) stay fixed inside.**

**'Giant' materials are like people (atoms) 'locked' in place at a *very* crowded concert, the DMV waiting room etc……**

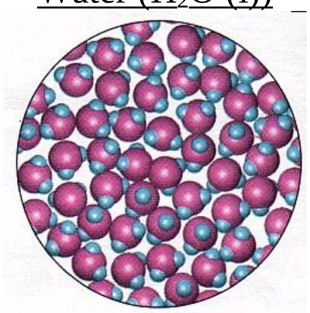
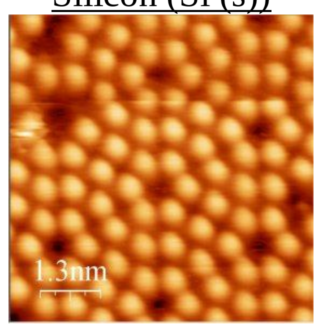
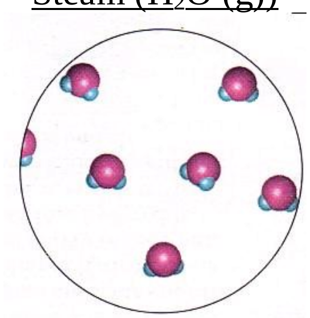
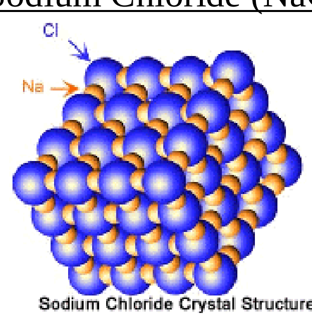
**A molecule is an independent unit containing two or more atoms**. *Remember the car / passenger analogy from above*

Task: Classify the following molecules as either elements or compounds




| | |
|---|---|
| HF: | $Br_2$: |
| $NH_3$: | $CCl_4$: |
| $CO_2$: | $N_2$: |

Wrap Up: A microscopic scale view of several materials is presented below. Label each using *elemental* or *compound* **and** *molecular* or *'giant'* tags

<table>
<tr>
<td>Water ($H_2O$ (l)) _<br></td>
<td>Silicon (Si (s))<br><br></td>
</tr>
<tr>
<td>Steam ($H_2O$ (g)) _<br></td>
<td>Sodium Chloride (NaCl)<br><br></td>
</tr>
</table>

**Pure Materials v Mixtures**

Recap: **Pure matter** is classed as ***either*** an ELEMENT ***or*** a COMPOUND.

**Elements can have *either* Molecular *or* 'giant' structures**. Examples: $N_2$ (g) (Nitrogen gas, molecular), Pb(s) (metallic lead, a 'giant' structure)

**Compounds can also have *either* Molecular *or* 'giant' structures.** Examples: $H_2O$(l) (water, molecular), $Fe_2O_3$(s) ('rust' (iron oxide), a 'giant' structure)

Discussion: Air contains a number of *different* components – what are they? How would you describe what air is made up from using words like element, compound, gas, molecular etc.?

**ANY combination of different types of matter 'placed together' is defined as a mixture (eg. air, milk, pepsi).**

**Mixtures are NOT pure materials** (eg. Pure gold (Au) vs 'white' gold* (Au+ Ag).

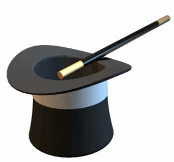
Mixtures can be either **HOMOGENEOUS** or **HETEROGENEOUS**.

*White gold is an example of a solid mixture, or ***alloy***. Others include…

**Further Definitions of a mixture**

<u>HOMOGENEOUS MIXTURE</u>:

<u>HETEROGENEOUS MIXTURE</u>:

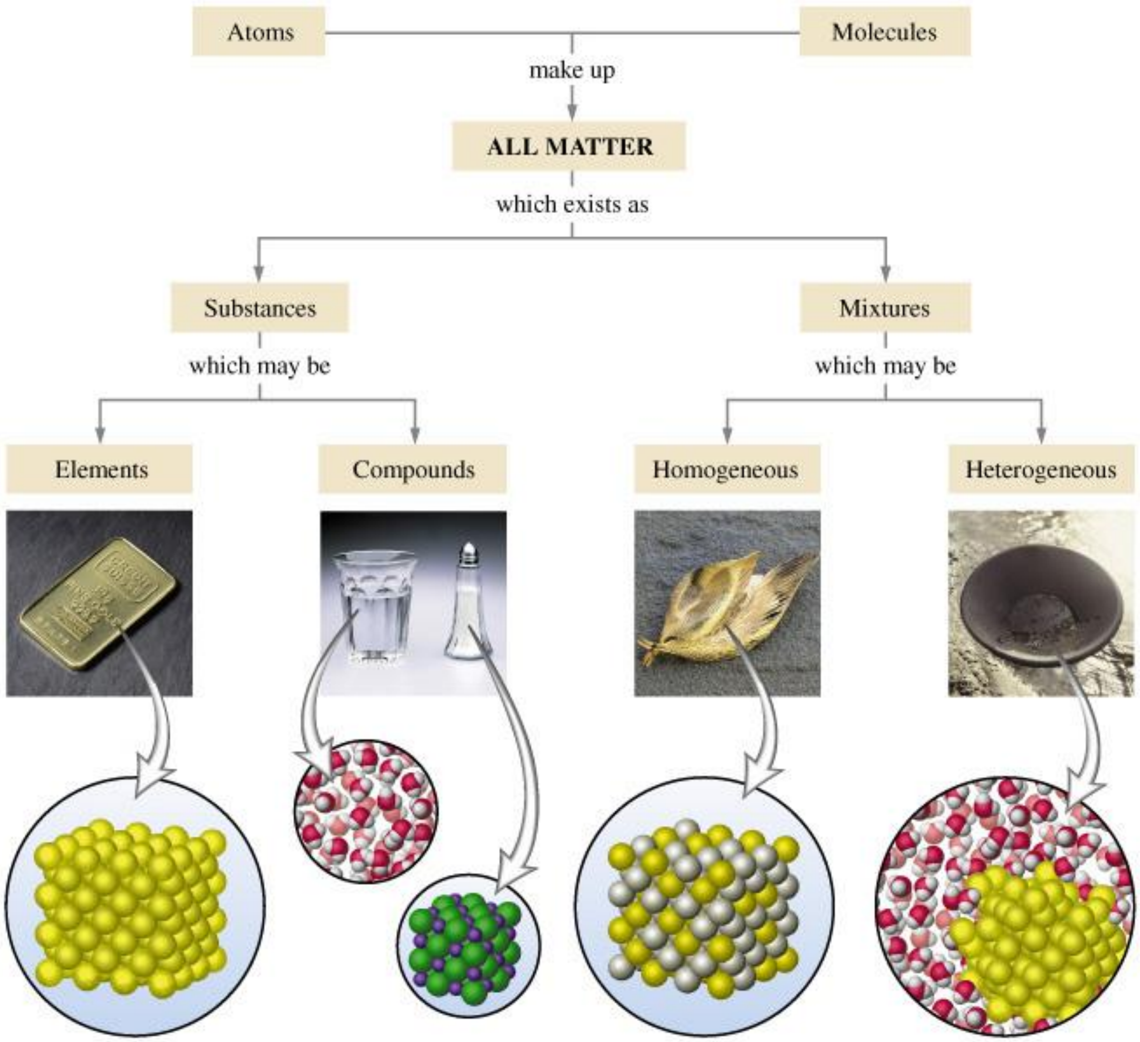


<u>Fact</u>: *Most* matter we interact with on a daily basis is in the form of a mixture.

Task: List four mixtures, and their components, *you* have interacted with today. Also state if your mixtures are *either* heterogeneous *or* homogeneous:

| Mixture Name | Components | Homogeneous? |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Classification of Matter Flowchart




Discussion: Dr. Mills really likes the above slide – why? Hint: What does a chemist do?

**Separating Mixtures**

Context: The separation of mixtures into their components is a widely used and important scientific method. For example, desalination plants on Navy vessels create drinking water by separating salt from seawater, while distillers separate alcohol from fermented ‘mash’ to make hard liquor.

Questions: How would you, using ‘everyday’ or simple lab equipment:

1. Separate the dissolved salt from seawater?

2. Separate and collect the alcohol from a water / alcohol mixture?

3. Separate a sand water mixture?

Discussion: Which chemical or physical properties of the components of a mixture do the separation methods rely on to 'get the job done'?

**Evaporation**:

**Distillation:**

**Filtration:**

**In the lab, industry, (or even in the 'back woods'), *three* main methods are typically used to separate the components of mixtures:**

**EVAPORATION - DISTILLATION - FILTRATION**

**These methods can be employed either *singularly* or *in sequence* to separate most any mixture.**

Task: Describe how the three components of a saltwater (dissolved salt + water) and sand mixture could be separated and collected.

## *"Mixtures, Elements and Compounds"*

The following questions were taken from your 1st practice midterm:

State whether the following are classified as elements, compounds or mixtures:

<u>Diamond</u>:

(giant) element

<u>Air</u>:

see class notes

<u>Water</u>:

(molecular) compound

<u>Oxygen gas</u>:

(molecular) element

<u>Fresh Milk:</u>

(homogeneous) mixture

<u>Ice Cube</u>

(giant molecular) compound

<u>Carbon dioxide gas</u>:

(molecular) compound

<u>A cup of coffee</u>:

(homogeneous or heterogeneous) mixture

<u>Sand ($SiO_2$)</u>:

(giant) compound

<u>Gasoline</u>

(homogeneous) mixture

<u>Gold:</u>

(giant atomic) element

<u>A jar containing $H_2$ and $O_2$ gasses:</u>

(homogenous mixture of molecular) elements

# Energy

| | | | |
|---|---|---|---|
| Reading: | Ch 10 sections 1 - 5 | Homework: | 10.1, questions 4, 6<br>10.2, question 10<br>10.5 question 22, 24, 28, 32* |

* = 'important' homework question

## Temperature and Energy

Discussion: What is heat, what is energy? How are these things related to temperature?

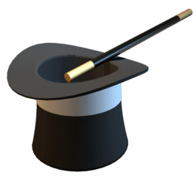
Recall: *Energy Content of Foods* Lab. The heat energy (-q) lost by food (when burnt) = heat energy (+q) gained by water in the soda can.

i.e. $$-\mathbf{q}_{\text{(food)}} = +\mathbf{q}_{\text{(water)}}$$

Notes: The sign (+ or -) indicates where the energy was lost (-) and where it was gained (+), in other words when it went 'from' (-) and 'to'(+). **The numerical value of q is the *same*, regardless of +/- signs, as the energy is *transferred* from the food to the water.**

Remember: q is measured in ________ , the S.I. unit of energy.

Task: What is an average person's daily Calorie requirement? A 'Big Mac' and large fries contains ~ 1100 calories - How many Big Mac extra value meals is can a person eat per day *and* stay within their recommended calorie limit (assume a diet coke!)? How many kJ is this equivalent to?



**To Convert J to Calories (the 'Jenny Craig unit of energy'), the following conversion identity must be used:**

$$1\ \text{Cal} = 4.184\ \text{kJ}$$

**Specific Heat Capacity ($C_p$)**

Definition: *The amount of heat energy required to raise the temperature of one gram of a substance by one degree Celsius*

In 'English':

Discussion: Would a material with a high or low heat capacity be best suited for use as radiator coolant? What other factors influence such a choice?


Table of Specific heat Capacities

| Substance | Sp. Ht. Cap. (J/g$^o$C) | Substance | Sp. Ht. Cap. (J/g$^o$C) |
|---|---|---|---|
| Water (l) | 4.18 | Mercury (l) | 0.14 |
| Water (s) | 2.03 | Carbon (s) | 0.71 |
| Aluminum | 0.89 | Silver (s) | 0.24 |
| Iron (s) | 0.45 | Gold (s) | 0.13 |

**Relating Energy (q), heat capacity ($C_p$) and temperature change ($\Delta T$)**

Recall: **Temperature is an *intensive* property** – it DOES NOT depend on the amount of material (a glass of water and a swimming pool full of water can have the same temperature).

**Energy is an *extensive* property** – it DOES depend on the amount of material (a glass of water and a swimming pool full of water contain very different amounts of energy at, say, room temperature).

Discussion: What properties of a material determine how much energy it can absorb before undergoes a change of state (e.g. factors influencing how *fast* a liquid boils)? Are these extensive or intensive properties?

| | Property | Effect and Reasoning | Intensive or Extensive? | Symbol |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

**The amount of heat energy transferred to or from any material or object can be found if its HEAT CAPACITY ($C_p$), MASS (g) and observed TEMPERATURE CHANGE, $\Delta$T ($^oC$ or K), it undergoes are known:**

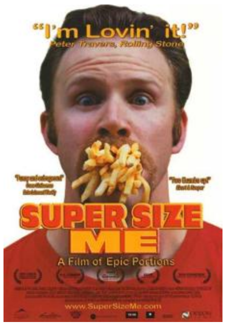
$$\mathbf{q = C_p \ x \ m \ x \ \Delta T}$$

<u>Questions</u>:

1. How much heat energy is needed to raise the temperature of 25 g water by 15$^o$C?

2. How much heat energy is needed to raise the temperature of 25 g solid iron by 15$^o$C?

3. How much heat energy would be needed to boil a 330 mL glass of water that is initially at room temperature (25 $^o$C)? How many Cal. is this? Density $H_2O$ (l) = 1.00 g/mL




<u>Questions of the week</u>: A certain Prof. was told that to lose weight he must consume no more than 1300 Cal per day and exercise for at least 60 minutes per week.

1. If the Prof. eats nothing but Big Mac value meals, how many can he eat per week and remain within his Cal per day limit?

2. The Prof's exercises for 90 minutes per week on his favorite exercise machine, which burns off 725 Cal/hr. In terms of energy, how many Big Mac value meals is this amount of weekly exercise equivalent to?

# Chemical Foundations – Part 1

| | | | |
|---|---|---|---|
| Reading: | Ch 4 sections 1 - 7 | Homework: | 4.1, question 4<br>4.2, questions 8, 10*<br>4.5, question 22<br>4.6 questions 24, 26, 28<br>4.7 questions 30, 34, 36*, 38*, 40*, 42* |

* = ‘important’ homework question

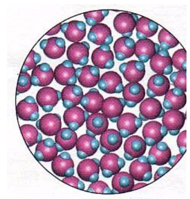
**Atoms and Isotopes**

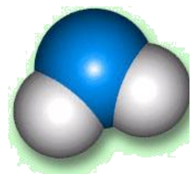
Discussion: In the preceding sections we took a brief look at different types of matter (i.e. elements, compounds and mixtures). These materials are made from smaller matter still – name as many of these fundamental ‘building blocks’ of matter as you can:

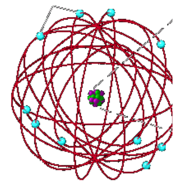
Question: How are these fundamental ‘building blocks’ of matter related?

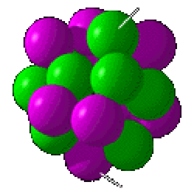
Fermi Lab, located in West Chicago, IL, is the world's largest 'atom smasher*'. Fermi is where scientists perform experiments in an attempt to understand the origins of the universe

Example: Water



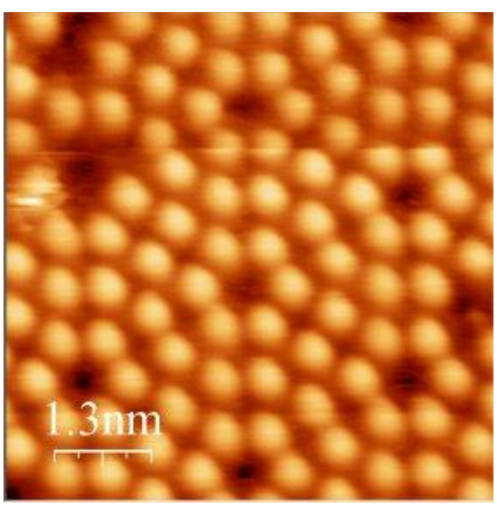






**Structure of the Atom**

Fact: Atoms are the smallest type of *stable* matter, they are typically spherical and have diameters of ~ 0.18 – 0.60 nanometers.




Shown on the left is an STM image of a silicon chip's (Si (s)) surface. Note that it has a repeating 'giant' structure.

Question: Based on the scale, what is the approximate width of a silicon atom in nm?

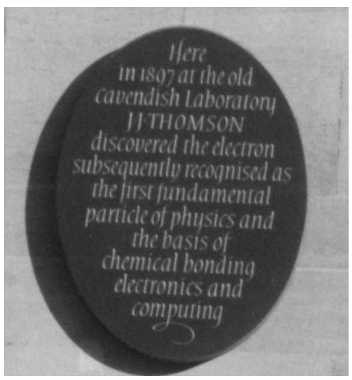
Answer:

Ask me about an extra credit assignment…

Questions:

1. What is at the center of an atom? What is this small central region of an atom called?

2. What two different types of subatomic particle are found inside the nucleus? (*sub*atomic means '*smaller than'* atomic)



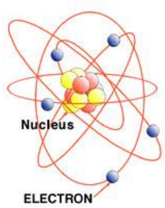

3. What 'orbits' the nucleus? (see slide)

4. Sketch a generic diagram of an atom using the slide as a guide. Based on the slide, how many times smaller is the diameter of the nucleus than the atom as a whole?

Comparison of subatomic particles (i.e. the things atoms are made from)

| Particle | Symbol | Charge | Relative mass |
|---|---|---|---|
| Electron | ***e*** | -1 | 1 |
| Proton | ***p*** | +1 | 1836 |
| Neutron* | ***n*** | 0 | 1839 |

* ask me to tell you a very poor neutron joke….




'Old style' model of the atom – electrons orbiting a central nucleus that, in turn contains protons and neutrons

Electrons are *much lighter* than the neutrons and protons (that, in turn, 'inhabit' the nucleus) ⇒ ELECTRONS MOVE MUCH MORE QUICKELY THAN THE NEUCLIUS EVER CAN (this is called the Born – Oppenheimer Approximation).

**This is why electrons are said to either 'orbit' the nucleus or exist as 'blurred out' electron 'clouds'.**

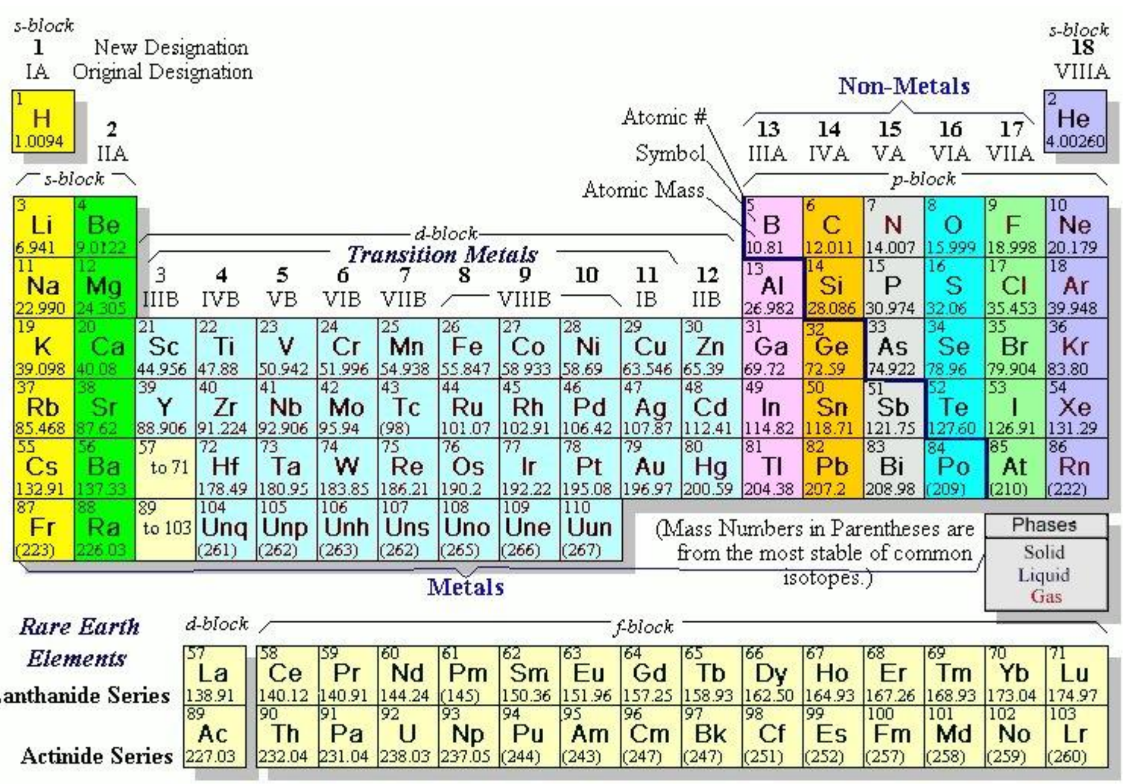
Question: Are ATOMS* electrically charged? Answer: ______

Question: What then must be true for EVERY atom in terms of the number of electrons and protons it contains?

*Aside: We saw/ will see in lab that ***ions*** are made by electrically charging atoms or molecules, we will meet this concept later.

Question: Where can we find out the number of protons (and therefore also the number of electrons) an atom has?

## The Periodic Table




 Note how the P. Table is *fundamentally* arranged in terms of *increasing* atomic number (Z)

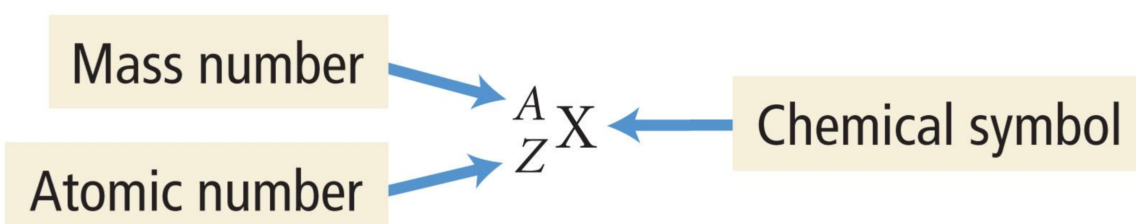
Note: We will typically use Roman numeral notation to assign groups (columns) in the P. Table, e.g. Carbon is the first element of group IVA.

Question: How many protons and electrons do the following atoms have?

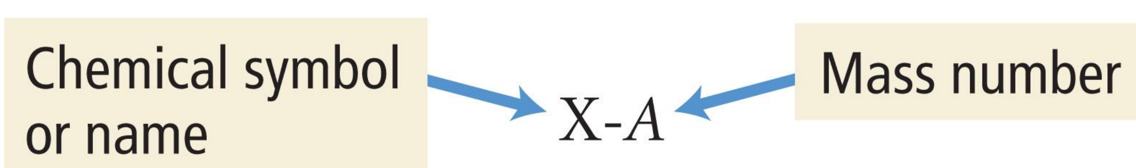
| Atom | #p | #e | Atom | #p | #e | Atom | #p | #e |
|---|---|---|---|---|---|---|---|---|
| Carbon (C): | | | Silicon (Si): | | | Lead (Pb): | | |

Question: What do you think the *other* number in an element's periodic table 'box' (e.g. Oxygen has '16.00') represents? How is this number determined?

**This information is summarized in an atom's COMPLETE ATOMIC SYMBOL:**



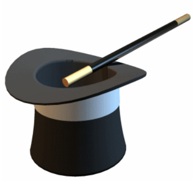

'Shorthand' version of the complete atomic symbol:



Task: Carbon–14 has a mass number of 14. Use this information to write its complete atomic symbol. Do the same for U-235.

* remind me to tell a story about U-235 and U-234

**Understanding Isotopes**

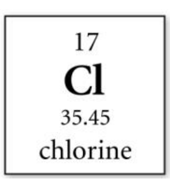


**An element has a FIXED number of protons in its nucleus.**

(This information is contained within the element's Atomic Number. Eg. All hydrogen (H) atoms have 1 proton in their nuclei, while all carbon (C) atoms have 6 protons in their nuclei).

**HOWEVER, an element can have a VARIABLE number of neutrons in its nuclei.**

**(This does NOT alter the identity of the element (#p same), but DOES make the element heavier or lighter (# n changed))**




**The AVERAGE atomic mass value for ALL an element's isotopes is displayed in the periodic table.**

E.g. Chlorine has a mass number of 35.45 amu* – there are *NO single* chlorine atoms in existence with a mass of 35.45 amu (i.e. no such thing as 0.45 of a neutron!), but there are Cl isotopes with mass numbers of 35 and 37 – their *weighted average* is 35.45 amu

Note: an amu is an **a**tomic **m**ass **u**nit – the mass of a ***single*** proton or neutron. This is $\approx 1.66053873 \times 10^{-24}$ g. It is *much* simpler to count atomic masses in amu – "an atom of carbon -12 (which contains 6 p and 6 n, so has a mass number of 12) weigh 12 amu" is better than saying "an atom of carbon -12 weigh $1.992648 \times 10^{-23}$ grams"!

Task: Complete the following table for the isotopes of Carbon. (Tip: what are the values of #p and #e ALWAYS for carbon? Where would you find this information?)

| Complete atomic Symbol | #p | #e | #n |
|---|---|---|---|
| | | | **5** |
| | | | **6** |
| | | | **7** |
| | | | **8** |


Discussion: Carbon Dating

*"Symbols"*

The following question was taken from your 2nd practice midterm:

Question 1 (25 points): Write complete atomic symbols for the isotopes described by:

1. A mass number of 14 and an atomic number of 6

2. A total of 30 neutrons and 25 protons in it's nucleus

3. A total of 47 electrons and a mass number of 109

4. The isotope of chlorine with a mass number of 37

5. The isotope of potassium with 20 neutrons

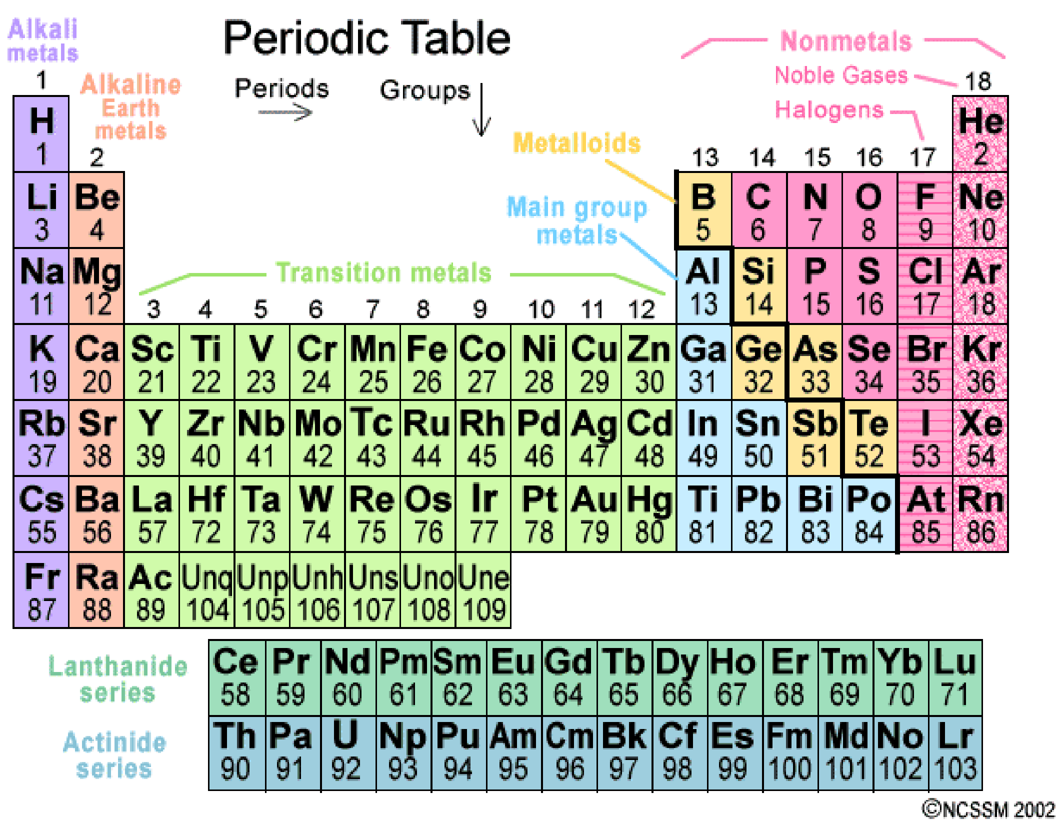
# Chemical Foundations – Part 2

| | | | |
|---|---|---|---|
| Reading: | Ch 4 sections 8 – 11<br>Ch 5 sections1 – 7 | Homework: | 4.8 question 44*, 48, 54<br>4.10 questions 66, 68, 70, 74*, 76<br>4.11 questions 80, 84* |
| Downloads: | Periodic table<br>Ion Chart | | 5.2 questions 10*, 12<br>5.5 questions 32, 34, 36*<br>5.6 question 40<br>5.7 questions 42* 50* |

* = 'important' homework question

## A More Detailed Look at the Periodic Table

Fact 1: The Periodic table is arranged left – right in order of increasing atomic number (Z) (i.e. each type of atom in the p. table has one more proton in its nucleus than its predecessor).




Example: Nitrogen is element number 7, while Oxygen, the next element, is atomic number 8.


Dmitri Mendeleev

Question of historical interest: Why is the periodic table not one continuous 'line' of elements, starting with Element #1 (H) and finishing with Element ~109?

In other words, why did early chemists, such as Mendeleev, start row (period) 2 with Lithium?

Fact 2

Question: Why is the periodic table so named? Hint: Look at the above P. Table's labels and color scheme

Fact 3

Question: If the classification of the elements is periodic, would you expect their physical and chemical trends to be so also?

Examples of Physical and Chemical trends within the Periodic table

| Left side (metals) | Right side (non-metals) |
| --- | --- |
| | |
| | |
| | |
| | |
| | |

**Making Ions**

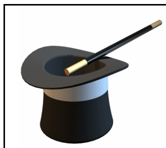
<u>Questions</u>: What are ions? How are they made?

<u>Ion:</u>

*<u>Atomic Ions:</u>

*ask me to tell you a *very* poor ion joke…

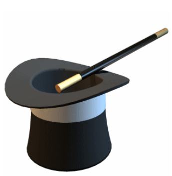
**Atomic (*micro*) scale diagram of Ionization and *macro* scale crystal growth (slide)**



**In reality, electron(s) are EXCHANGED between** atoms in order to become ionic compounds. I.E. what is lost by the metal (to become an $M^{n+}$ cation) is gained by the non-metal (to become $A^{n-}$ anion)

**Making and Naming Ionic Formulas**

<u>List of Common atomic ions (must learn)</u>: See handout provided



| Group I | Group VII |
|---|---|
| Group II | Group VI |
| Group III | Group V |

<u>Naming atomic ions</u>: An atomic (+ve) cation has the same name as the metal it was formed from. An atomic (-ve) anion has the *same root* as the non-metal it was formed from, **but** and *–ide ending*. <u>Examples</u>:

| Metal atom | Metal cation | Non-metal atom | Non-metal anion |
|---|---|---|---|
| Na | | Cl | |
| Mg | | O | |

**Ionic formulas are made by combining ANY cation (+ve) with any anion (-ve).**

**The order in ANY ionic formula is cation first, anion second, in *both* formula and name. i.e. (cation)(anion)**

<u>Examples</u>: NaCl (sodium chloride)

LiF (                                        )

**Ionic formulas ALWAYS have a ZERO net charge – i.e. the (+) and (-) ionic charges in ANY formula cancel.**

If the above rule is followed, the ionic compound must exist and is probably sitting on a shelf in the chemistry stock room!

Task: Construct and name as many ionic compounds as possible from the following ions:

$Li^{+}$ $Ca^{2+}$ $Al^{3+}$ $Cl^{-}$ $O^{2-}$ $N^{3-}$

List of Common molecular ions (must learn): See attached handout.

Trick – many *molecular ions* appear on the data sheet (see handout). Just keep using (homework) and/or looking (fridge) at the rest

Naming molecular ions:

**There is ONLY one molecular cation – $(NH_4)^{+}$, ammonium**.

**Molecular anions with NO (or very few*) oxygen atoms in their structure have the –*ide* ending**. Examples: $^{-}OH$ (hydrox*ide*)*, $CN^{-}$ (cyan*ide*)

**Molecular anions with 'lots' of oxygen atoms in their structure have the –*ate* ending**. Examples: $(SO_4)^{2-}$ (sulf*ate*), $(NO_3)^{-}$ (nitr*ate*), $(CO_3)^{2-}$ (carbon*ate*), $(PO_4)^{3-}$ (phosph*ate*)

**Recall: Ionic formulas ALWAYS have a ZERO net charge – i.e. the ionic charges in ANY formula cancel.**

This is true for molecular ions too – just treat the whole molecular ion as if it were an atomic ion when making the formula. Name the resulting compound in a similar way also.

Task: Construct and name as many ionic compounds as possible from the following ions:

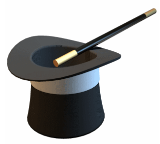
$Li^{+}$ $Mg^{2+}$ $(NH_4)^{+}$ $(NO_3)^{-}$ $(SO_4)^{2-}$ $(PO_4)^{3-}$

Naming Ionic compounds containing a cation of variable charge

**Metallic elements from the center of the periodic table (the *transition series*, between groups II and III) can form atomic ions with a range of +ve charges. Examples: $Fe^{2+}$ and $Fe^{3+}$, $Cu^{+}$ and $Cu^{2+}$.**

Question: Can you see a potential problem with regard to writing the names and formulas of ionic compounds containing such cations?

Answer:

Ionic formulas featuring a variable charge (oxidation state) cation include the charge of the cation (written in Roman numerals) in the formula name. E.g.: $Cu_2O$ = Copper(I) oxide

Task: Complete the following table:

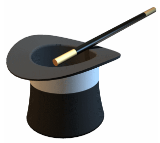
| Name | Formula | Name | Formula |
|---|---|---|---|
| Iron (II) Sulfate | | Copper (I) Phosphate | |
| | $Cu(NO_3)_2$ | | $FeCl_3$ |

**Acids and bases**

Discussion: Are acids and bases typically ionic or molecular compounds (recall your recent lab)? What is 'special' about their formulas?

Naming acids and bases: There are two ways of naming acids, and one way for bases:

1. Just use the standard approach for naming ionic compounds:



Remember:

**$H^+$ = 'hydrogen' ion, $^-OH$ = 'hydroxide' ion**

Task: Name the following acids and bases using standard ionic compound nomenclature:

| | |
|---|---|
| HCl | NaOH |
| $H_2SO_4$ | $Ca(OH)_2$ |
| $HNO_3$ | $Al(OH)_3$ |

2. Using common nomenclature (chemical 'nicknames', must learn)

Rules: Acids with *–ide* anions (e.g. Chloride, $Cl^-$) have a '*hydro*' prefix and an '*–ic'* ending, followed by 'acid'.

Example: HCl = *Hydro*chlor*ic* acid

Task: name the following acids:

| | |
|---|---|
| HBr | HI |
| HCN | $H_2S$ |

Acids with molecular *'–ate'* anions, such as nitrate, $(NO_3)^-$, and sulfate, $(SO_4)^{2-}$, simply become *'–ic* acids':

<u>Example</u>: $H(NO_3)$ = nitr*ic* acid

<u>Task</u>: name the following acids:

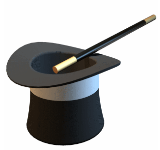
$H_2SO_4$

$H_3PO_4$

$H_2CO_3$

<u>Question of the week - Group work</u>

Understanding ionic formulas is 'all about' practicing writing and naming ionic formulas.



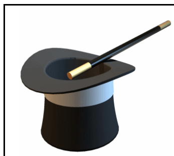
**<u>Recall</u>:**

**Ionic formulas ALWAYS have a ZERO net charge – i.e. the ionic charges in ANY formula cancel.**

**Ionic compounds are named (cation name) (anion name)**

The group work outlined below will cement your knowledge of ionic compounds…

<u>Task</u>: Complete tables 5.A (write formulas) and 5.B (write formulas) – both on (p 138). Work in groups for two or three, write you answers in the blank tables provided:



<u>Tip</u>: *This may take a while, but it is worth it*. If you can do this task the exam questions will seem easy…….

Table 5A: Make ionic formulas from ion formula pairs

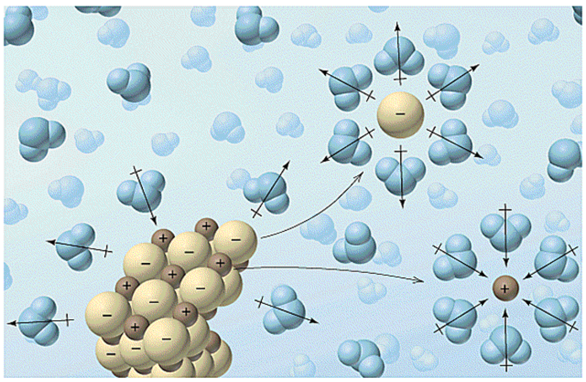
| Ions | $Fe^{2+}$ | $Al^{3+}$ | $Na^{+}$ | $Ca^{2+}$ | $NH_4^{+}$ | $Fe^{3+}$ | $Ni^{2+}$ | $Hg_2^{2+}$ | $Hg^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|
| $CO_3^{2-}$ | $FeCO_3$ | | | | | | | | |
| $BrO_3^{-}$ | | | | | | | | | |
| $C_2H_3O_2^{-}$ | | | | | | | | | |
| $OH^{-}$ | | | | | | | | | |
| $HCO_3^{-}$ | | | | | | | | | |
| $PO_4^{3-}$ | | | | | | | | | |
| $SO_3^{2-}$ | | | | | | | | | |
| $ClO_4^{-}$ | | | | | | | | | |
| $SO_4^{2-}$ | | | | | | | | | |
| $O^{2-}$ | | | | | | | | | |
| $Cl^{-}$ | | | | | | | | | |

Table 5B: Make ionic formulas from ion name pairs

| Ions | nitrate | sulfate | hydrogen sulfate | dihydrogen phosphate | oxide | chloride |
|---|---|---|---|---|---|---|
| calcium | $Ca(NO_3)_2$ | | | | | |
| strontium | | | | | | |
| ammonium | | | | | | |
| aluminum | | | | | | |
| iron(III) | | | | | | |
| nickel(II) | | | | | | |
| silver(I) | | | | | | |
| gold(III) | | | | | | |
| potassium | | | | | | |
| mercury(II) | | | | | | |
| barium | | | | | | |

## Electrolytes

Recall your lab: What is an electrolyte? Why do sports drinks contain electrolytes?



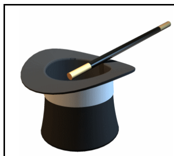
Task: Using the slides and figure to help you, write a description of how solutions containing *strong electrolytes* are formed:

Most ionic compounds dissolve in water ⇒ they MUST dissociate ('break apart) to form an *electrolytic solution*. The dissolved ions are called *electrolytes*. See slide and figure.

Example: 'pasta water'

$$NaCl(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$$

(aq) is a state symbol which means 'dissolved' or 'with water'



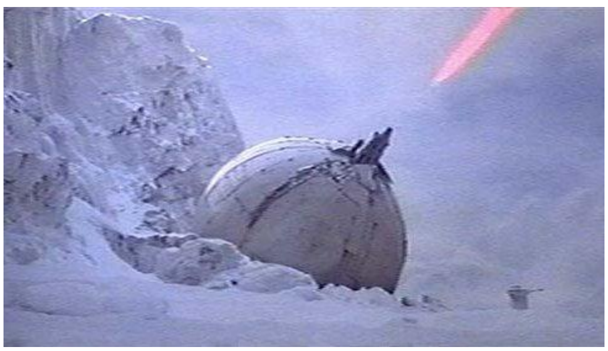
***Mobile* (aq) ions conduct electricity** ⇒ *all* electrolytic solutions conduct electricity.

The 'stronger' the electrolytic solution is, the more ions there are in solution and more electricity can be conducted

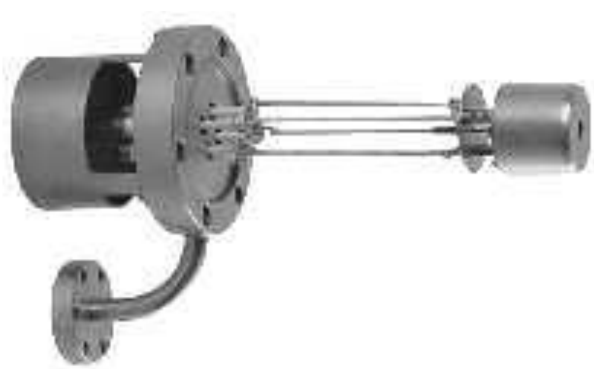
**Ions in the Movies – Science fact or Science fiction?**

Discussion: What makes for a good sci-fi movie? Why was *Star Wars* ‘good’ and *Battlestar Galactic* (released at the same time) ‘bad’??

'Bad Guy' Brian Cox




An ion cannon, as seen in *The Empire Strikes Back* has a lot in common with a computer technician’s static-guard wrist strap – electrical discharges can ‘fry’ sensitive electronics




Actual ion guns, used in surface science research and microchip manufacture.

Discussion: Would a commercially available ion gun be any use for ‘home defense’??

“Ionic”

The following question was taken from your 2nd practice midterm:

Question 2a (18 points): Write the formulas and names of nine ionic compounds that may be formed through combining the anions and cations ions listed immediately below.

$H^{+}$ $Cu^{2+}$ $Al^{3+}$ $Cl^{-}$ $SO_4^{2-}$ $PO_4^{3-}$

| Ionic Formula | Name of Ionic Compound |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

# Chart of the Common Ions (Learn)

| **+1 ions** | **+2 ions** | **+3 ions** | **-3 ions** | **-2 ions** | **-1 ions** |
|---|---|---|---|---|---|
| $H^+$ | $Mg^{2+}$ | $Al^{3+}$ | $N^{3-}$ | $O^{2-}$ | $F^-$ |
| $Li^+$ | $Ca^{2+}$ | $Fe^{3+}$ | | $S^{2-}$ | $Cl^-$ |
| $Na^+$ | $Sr^{2+}$ | $Cr^{3+}$ | $PO_4^{3-}$ | | $Br^-$ |
| $K^+$ | $Ba^{2+}$ | | (phosph*ate*) | $SO_4^{2-}$ | $I^-$ |
| $Au^+$ | $Cu^{2+}$ | | | (sulf*ate*) | |
| $Ag^+$ | $Zn^{2+}$ | | | $CO_3^{2-}$ | $^-OH$ (hydrox*ide*) |
| $Cu^+$ | $Fe^{2+}$ | | | (carbon*ate*) | $NO_3^-$ (nitr*ate*) |
| $NH_4^+$ | $Pb^{2+}$ | | | | $CN^-$ (cyan*ide*) |
| (ammonium) | | | | | |

Solubility rules (will be covered in later handouts):

| **Soluble Compounds** | | Exceptions |
|---|---|---|
| Compounds containing | $NO_3^-$ | None |
| | $Cl^-$ | $Ag^+$, $Hg^{2+}$,$Pb^{2+}$ |
| | $Br^-$ | $Ag^+$, $Hg^{2+}$,$Pb^{2+}$ |
| | $I^-$ | $Ag^+$, $Hg^{2+}$,$Pb^{2+}$ |
| | $SO_4^{2-}$ | $Ba^{2+}$, $Hg^{2+}$,$Pb^{2+}$ |

| **Insoluble Compounds** | | Exceptions |
|---|---|---|
| Compounds containing | $CO_3^{2-}$ | $NH_4^+$ & group IA cations |
| | $PO_4^{3-}$ | $NH_4^+$ & group IA cations |
| | $OH^-$ | group IA cations $Ca^{2+}$,$Sr^{2+}$, $Ba^{2+}$ & $NH_4^+$ |

Tricks:

Group # = ion charge for metal ions, e.g. Li (group 1) = +1

-(8 –group #) = ion charge for atomic non-metal ions, e.g. O = -(8-6) = -2

Formulas for most molecular ions appear on the solubility chart (supplied in data sheet).

# Chemical Reactions – Part 1

| Reading: | Ch 6 sections 1 - 3 | Homework: | 5.3 questions 17, 18, 22*<br>6.1 question 2<br>6.2 questions 8, 12, 14, 16, 22 |
|---|---|---|---|

* = 'important' homework question

## Overview of Bonding Types

As we saw in previous work, **metals react with non-metals to form ionic compounds**:

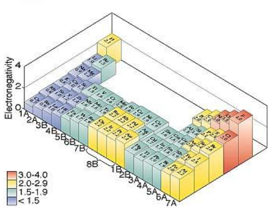
Example: Na(s) + $Cl_2$(g) → NaCl(s)  (recall slide)

(i.e. sodium metal + chlorine gas → sodium chloride)

**Ionic compounds are only formed between metals* (forming cations) and non-metals (forming anions)**

**Recall: Metals appear on the LEFT of the periodic table and non-metals on the RIGHT.** Thus mixing a 'leftie' with a 'rightie' results in the formation of an ionic compound (see above example).

Discussion: When two non-metals are mixed (both from the right of the periodic table) would you expect an ionic bonded product? Explain*.



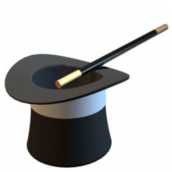

* Electronegativities: see slide at end of handout

**Atoms close to one another in the P. table (two 'righties') have *similar* electronegativity values ⇒ they SHARE electrons and form COVALENTLY bonded MOLECULAR products**

Example: $C(s) + O_2(g) \rightarrow CO_2(g)$ (molecular compound)

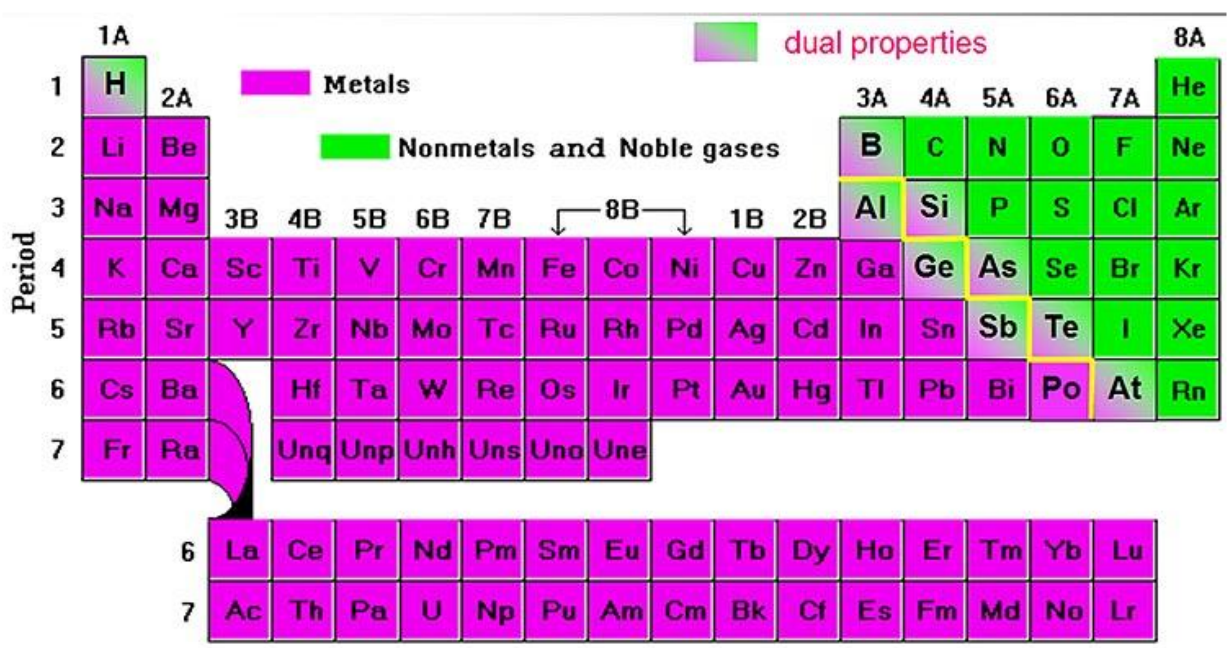
**Atoms distant from to one another in the P. table ('leftie' and 'rightie') have *dissimilar* electronegativity values ⇒ they EXCHAGE electrons and have IONIC bonded GIANT products**

Example: $Na(s) + Cl_2(g) \rightarrow NaCl(s)$ (giant ionic compound)



# *Location, Location, Location!*

**Metallic vs Non metallic Elements in the Periodic Table**



**ONLY a non-metal (top RHS) bonded to metal (LHS) make *giant compounds with ionic bonds*. E.g. NaCl, MgO**

**THESE MATERIALS ARE NAMED IN ACCORDANCE WITH THE 'IONIC' RULES DISCUSSED PREVIOUSLY**

**ONLY a non-metal bonded to another non-metal (top RHS p. table) make *molecular materials* with *covalent bonds*. E.g. CO, $H_2O$, $SO_3$**

**THESE MATERIALS ARE NAMED IN ACCORDANCE WITH THE (BELOW) 'MOLECULAR' RULES**

Task: Based on the following materials' formulas, predict if each possesses *either* covalent *or* ionic bonding and if each has *either* a giant *or* molecular structure. Hint: recall the 'dividing line' in the p.table

| Material | Bonding | Structure |
|---|---|---|
| Water ($H_2O$) | | |
| Table salt (NaCl) | | |
| Nitrogen gas | | |
| Rust ($Fe_2O_3$) | | |

Question: What important relationship do you see between bonding and structure?

**Naming Molecular Elements and Compounds**


Task: Write the formula of *and* name as many molecular elements and compounds as you can

| Formula | Name | Formula | Name |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

Discussion: What relationships do you see between the names and formulas of molecular compounds?

| |
|---|
| |
| |
| |

Prefix Table

| Number of atoms | Prefix* | Example |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

*Prefixes are dropped for the first *single* atom in a formula. E.g. $CO_2$ is named ‘Carbon dioxide’, not ‘Mono Carbon dioxide’.

Tasks:

Name the Following:

$NF_3$

$Cl_2O$

$P_2O_5$

Write formulas for the following:

Chlorine dioxide

Chlorine pentafluoride

Dihydrogen mono sulfide*

* If named using ionic nomenclature, also known as ___________________

**Types of Chemical Reactions**

Fact: There are FIVE general types of chemical reactions (recall your lab).

1. Combination Reactions - two or more types of material become one new material:

   Generic: A + Z $\rightarrow$ AZ

   Example: $C(s) + O_2(g) \rightarrow CO_2(g)$

   Note: All combustion (adding oxygen) reactions are classed as combination reactions.

2. Decomposition Reactions - a material becomes two or more new materials:

   Generic: AZ $\rightarrow$ A + Z

   Example: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

   Note: Decomposition reactions may be considered the reverse of combination reactions.

3. Single Replacement ('Prom') reactions - a more reactive material replaces a less reactive one in a compound:

*Random internet prom pic.*

   Generic: A + BZ $\rightarrow$ AZ + B

   Example: $Sn(s) + 2HCl(aq) \rightarrow SnCl_2(aq) + H_2(g)$

   Note: The material replaced (B or $H^+$ above) is said to be LESS reactive than it's replacement (A or Sn above).

4. Double Replacement reactions - the respective ionic partners of a pair of dissolved ionic compounds are swapped, most often resulting in the formation of solid product(s):

*gerr!*

Generic: AX + BZ → AZ + BX

Example: $AgNO_3$(aq) + NaCl(aq) → AgCl(s) + $NaNO_3$(aq)

Note: These types of reactions typically take place between dissolved ionic compounds, and typically result in one of the new materials forming a solid precipitate (ppt).

5. Neutralization reactions - very similar to double replacement, but ALWAYS between an acid and a base:

Generic: HA + MOH → MA + HOH
(acid + base → salt + water, $H_2O$)

Example: HCl(aq) + NaOH(aq) → NaCl(aq) + $H_2O$(l)

Note: These types of reactions are called neutralizations because acid ($H^+$) and basic ($OH^-$) ions react with each other to form water ($H_2O$). Such reactions typically liberate large amounts of heat (highly exothermic).

Task: Identify the following reactions (some of which you may remember from lab) as either: *combination*, *decomposition*, *single replacement*, *double replacement* or *neutralization*. **Additionally, write the formula equivalent of each reaction below its word equation version**.

sulfur(s) + oxygen gas → sulfur dioxide gas

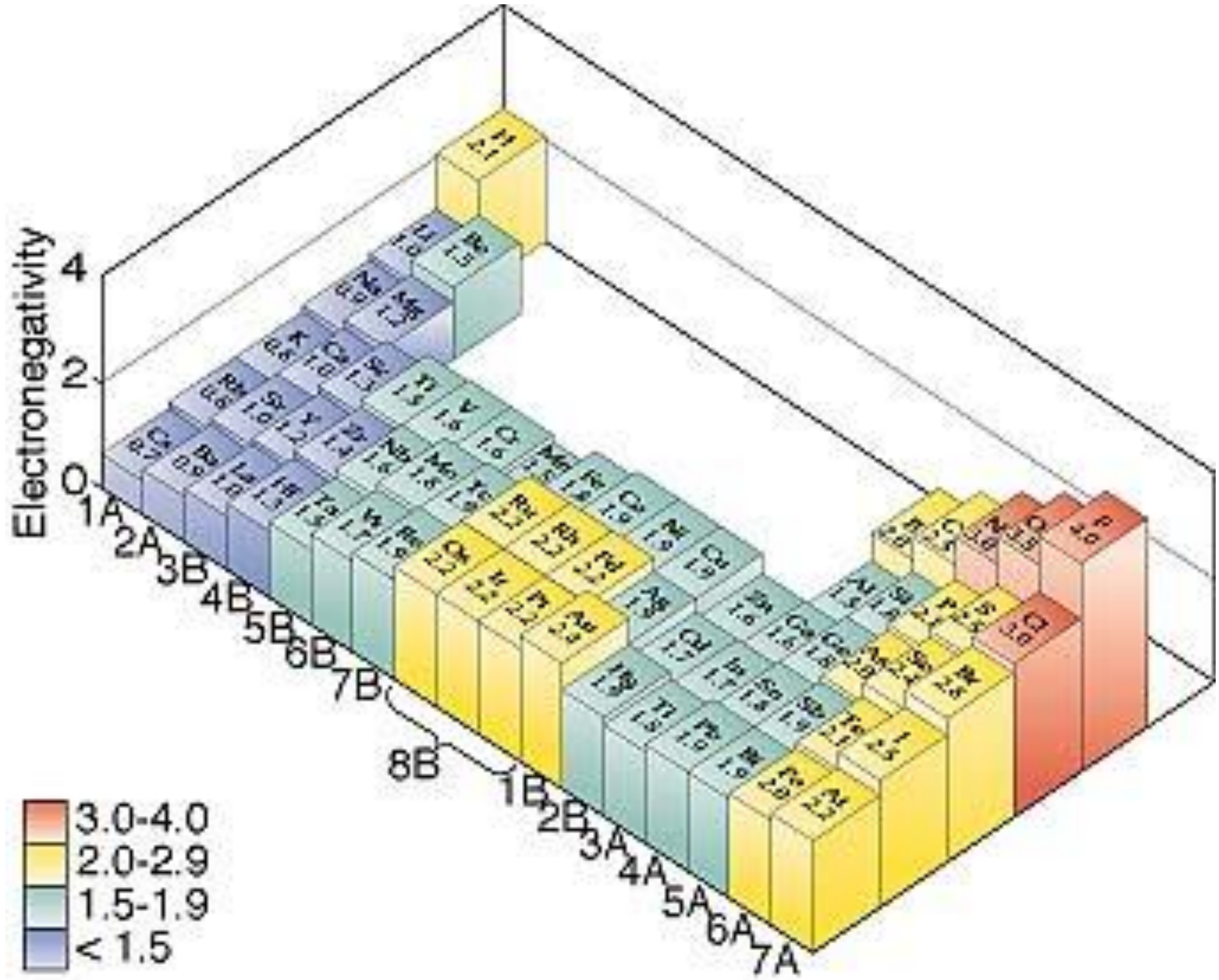
magnesium carbonate(s) → magnesium oxide(s) + carbon dioxide gas

zinc(s) + copper (II) nitrate sol$^{n}$. → metallic copper + zinc nitrate sol$^{n}$.

silver nitrate(aq) + sod. chloride(aq) → silver chloride(s) + sod. nitrate (aq)

sodium hydroxide solution + hydrochloric acid solution →

**Electronegativity Values**




Electronegativity ‘map’ of the periodic table – this and other periodic trends will be covered in more detail later in the course

# Chemical Reactions – Part 2

| | | | |
|---|---|---|---|
| Reading: | Ch 7 sections 1 - 7 | Homework: | 6.3 questions 38*, 40*, 42, 44<br>7.2 questions 4, 12*, 14, 16*<br>7.3 questions 26*, 28<br>7.4 questions 38, 40 |

* = ‘important’ homework question

### Balancing Chemical Equations

**Law of Conservation of Mass: Atoms are neither created nor destroyed during a chemical reaction - *they just change, add or lose partners*:**

$$C\ (s) \quad + \quad O_2\ (g) \quad \rightarrow \quad CO_2\ (g)$$

What does each symbol represent in the above chemical reaction?

| Symbol | Represents | Symbol | Represents |
|---|---|---|---|
| **C(s)** | A single atom of carbon in the charcoal brick (a reactant) | → | A chemical symbol meaning ‘goes to’ or ‘is converted in to’ |
| **$O_2$(g)** | A single molecule of oxygen gas from the air (a reactant) | **$CO_2$ (g)** | A single molecule of carbon dioxide gas produced from the reaction (the product) |

Since there must (by definition) be the same number and type of each atom on both sides of the equation (i.e. *before* and *after* the reaction). The reactants and products must also have equal masses. Why?

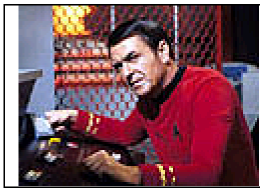
**Mass Reactants lost = Mass Products gained for ANY reaction**

Example: If 5.00 g of carbon is burnt in air to subsequently form 18.3g of carbon dioxide. How much oxygen gas (from the air) is used in this process?

$$C\ (s) \quad + \quad O_2\ (g) \quad \rightarrow \quad CO_2\ (g)$$

Application: Rules for balancing chemical equations

**1. Construct an *unbalanced* equation (sometimes using a word equation, as in lab). MAKE SURE THE FORMULAS ARE CORRECT, ONCE THEY ARE, DON'T 'MESS' WITH THEM!**

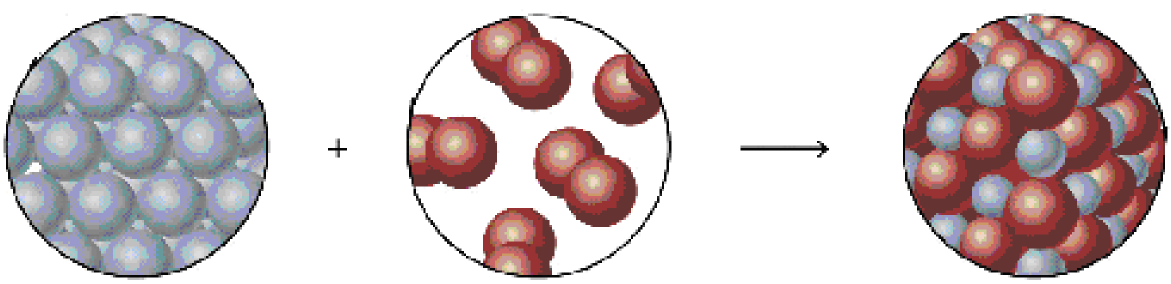


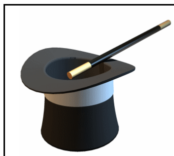
**'Captain, I can 'ney change the laws 'o physics!'**

***….or chemistry either, Scotty* – CORRECT CHEMICAL FORMULAS CAN NOT BE ALTERED ONCE WRITEN!**

E.g.: Write an *unbalanced* equation using formulas for the combustion of magnesium (as seen in lab).

Magnesium metal (s) + Oxygen gas $\rightarrow$ Magnesium Oxide (s)





**You know how to identify and write the name of either ionic or covalent (molecular) materials. What's the trick?**

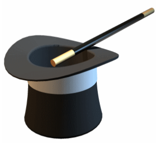
**$\Rightarrow$ Simply convert names to formulas first**

**2. Use *balancing numbers* (whole numbers that appear IN FRONT of formulas) to balance the equation: i.e. ensure that the law of conservation of mass is obeyed.**

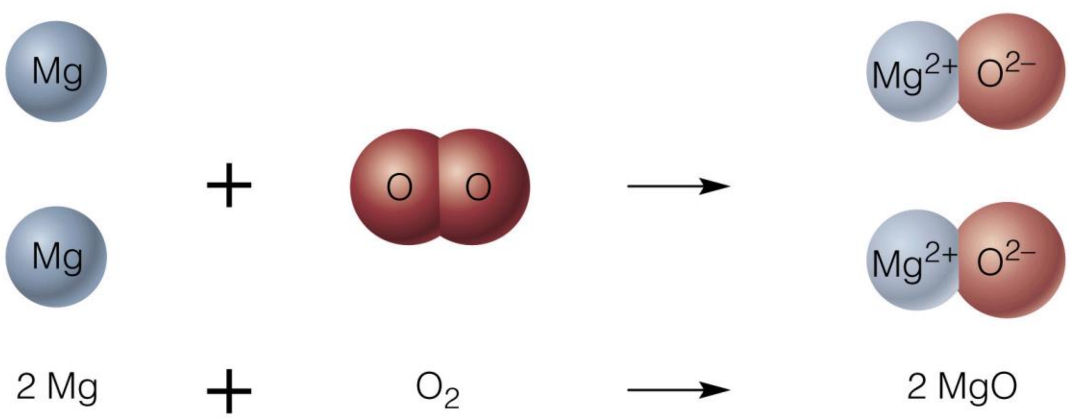
**UNDER NO CIRCUMSTANCES BE TEMPTED TO CHANGE THE FORMULAS!**

E.g.: Balance the following equation:

$$\_\_\_\ Mg\ (s) + \_\_\_\ O_2\ (g) \rightarrow \_\_\_\ MgO\ (s)$$

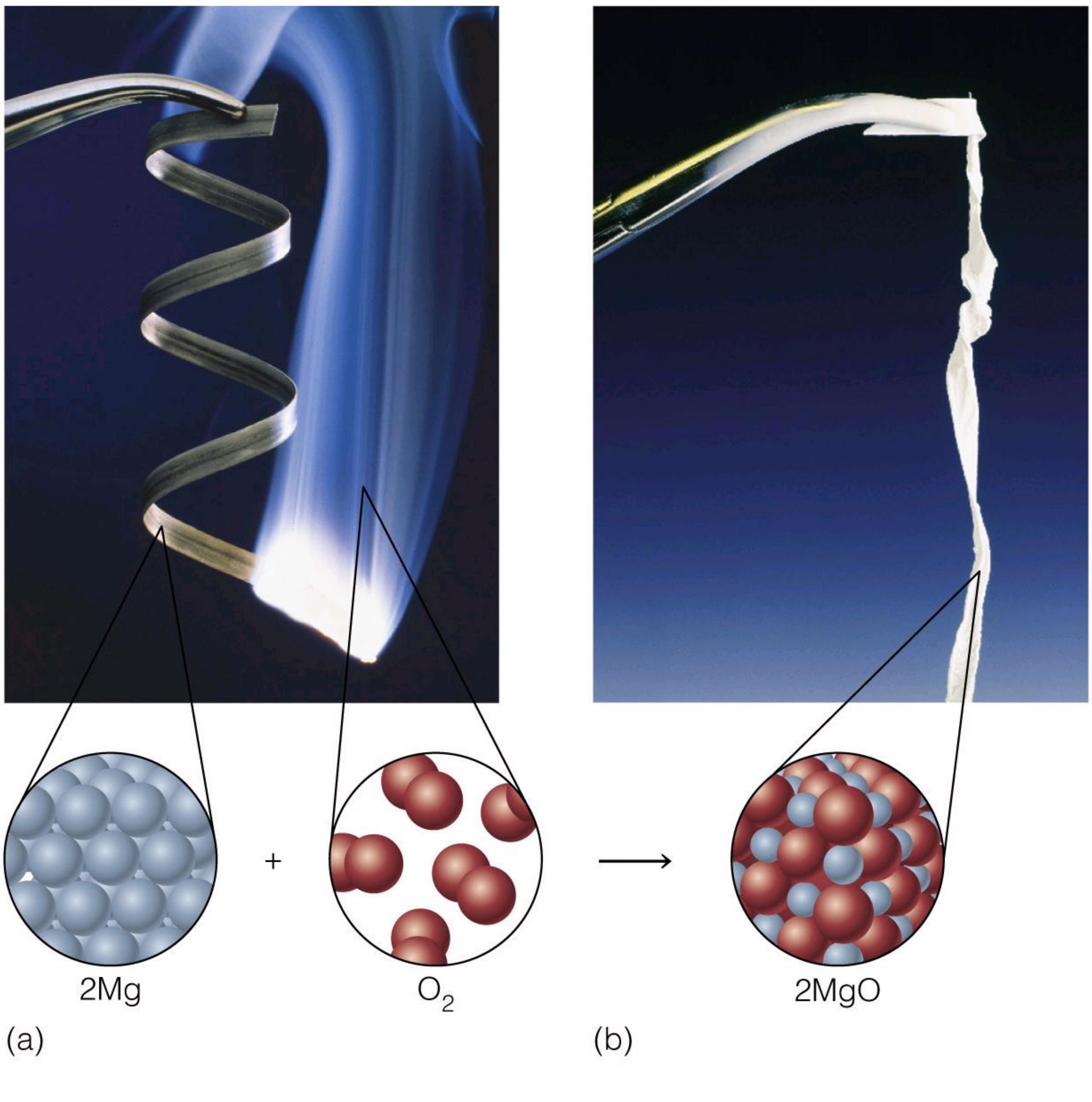
| | |
|---|---|
|  **Apply the 'tennis' approach:**<br><br>**Balance a single type of atom on the left, then see what happens on the right; then balance a different type of atom on the right, then see what happens on the left etc. until done.** | Walk through:<br><br>Balance # Mg atoms left and right<br><br>Balance # O atoms left and right<br><br>(re) Balance # Mg atoms left and right - |

Micro scale view:



Wrap Up: Remember this?! A combined *macro*scopic (pictures) and *micro*scopic (balanced chemical equation and cartoon) view of a familiar chemical reaction.

Remember: A chemist explains macro-scale phenomena in terms of a single (repeated many, many times….) microscopic description

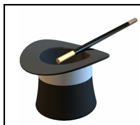


Task: Work in small groups to write balanced equations for the following.

1. The combustion of hydrogen gas to make water (see slides)

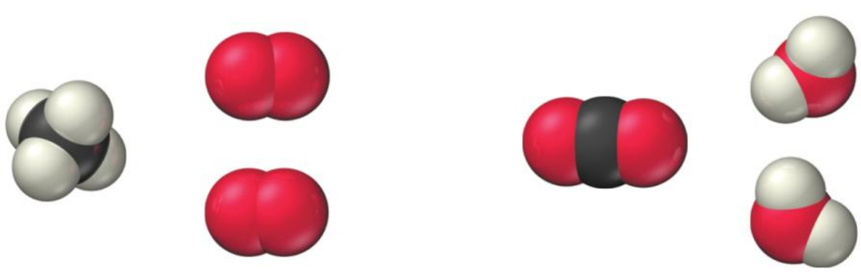
2. The combustion of sodium metal to make its oxide

3. The combustion of methane ($CH_4$).



**The products of combustion for *organic* materials are carbon dioxide and water.** Use the 'tennis' approach for balancing the C, H and then O atoms in order for organic (C, H and/or O containing) molecules

$$CH_4(g) + 2\,O_2(g) \longrightarrow CO_2(g) + 2\,H_2O(g)$$



4. The combustion of sugar ($C_6H_{12}O_6$).

5. The combustion of aluminum

6. The dissolving of sodium metal in water to give sodium hydroxide and hydrogen gas.

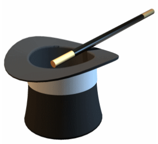
7. The reaction of glass ($SiO_2$(s)) with hydrofluoric acid to give silicon tetrafluoride gas and water.

8. (Harder) The reaction of ammonia gas ($NH_3$) with oxygen gas to give nitrogen monoxide gas and steam.

Recap of skills learnt so far:

- Be able to write balanced chemical equation from a word description of the chemical process (this is what you are often required to do in lab)
- Be able to identify any reaction as belonging to one of the 5 general types of reaction - *combination*, *decomposition*, *single replacement*, *double replacement* or *neutralization*.

Tricks



**1. Construct an *unbalanced* equation (sometimes from a word equation). MAKE SURE THE FORMULAS ARE CORRECT. ONCE THEY ARE, DON'T 'MESS' WITH THEM!**

**2. Use *balancing numbers* (whole numbers that appear IN FRONT of formulas) to balance the equation: i.e. ensure that the law of conservation of mass is obeyed.**

Tip: Apply the 'tennis' approach when balancing equations - balance a single type of atom on the left, then see what happens on the right; then balance a different type of atom on the right, then see what happens on the left etc. until done.

**UNDER NO CIRCUMSTANCES BE TEMPTED TO CHANGE THE FORMULAS WHEN BALANCING AN EQUATION**

Review Question: Write a balanced reaction for the combustion of propane ($C_3H_8$(g)) in air. What general type of reaction is this?

**Reactions in Aqueous Solutions**

Task: Write balanced chemical equations for the following reactions; also identify the *type* of reaction in each case. You may recall some reactions from lab.

1. The reaction of aqueous silver nitrate with aqueous sodium chloride to give solid silver chloride and sodium nitrate solution.

2. The decomposition of solid sodium hydrogen carbonate to solid sodium carbonate, water and carbon dioxide gas.

3. The reaction of copper metal with aqueous silver nitrate to form solid silver and aqueous copper (II) nitrate.

4. The neutralization of hydrochloric acid solution with calcium hydroxide solution.

Discussion: What do you think makes each of the above reactions 'go'? What is the driving force in each case?

Discussion: What evidence is there that the products are more stable than the reactants in each or the above processes? How are the reactants and products different on a micro and macro scale?

**1.**

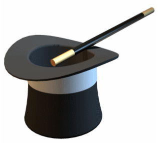
**2.**

**3.**

**Reactions in which a solid product (precipitate, ppt.) forms**

Worked example: Write ***balanced*** (molecular), ***complete*** and ***net*** ionic equations for the reaction of silver nitrate and sodium chloride solutions.

The Balanced (molecular) ionic equation



**This is the balanced, ionic double replacement ('swapping partners') reaction you are already familiar with.**

Balanced:

Question: How do we know which one of the products formed (AgCl or $NaNO_3$) is the solid recovered from the reaction?

**Whether or not an ionic material is soluble in water is known. This data appears in the solubility chart.**

**⇒ Determine if the product(s) are soluble via the chart and include the appropriate state symbol(s) in the balanced equation. ALWAYS INCLUDE STATE SYMBOLS IN ALL YOUR BALANCED, COMPLETE AND NET EQUATIONS**

Solubility chart (will be supplied)

| **Soluble Compounds** | | Exceptions |
|---|---|---|
| Compounds containing | $NO_3^-$ | None |
| | $Cl^-$ | $Ag^+$, $Hg^{2+}$, $Pb^{2+}$ |
| | $Br^-$ | $Ag^+$, $Hg^{2+}$, $Pb^{2+}$ |
| | $I^-$ | $Ag^+$, $Hg^{2+}$, $Pb^{2+}$ |
| | $SO_4^{2-}$ | $Ba^{2+}$, $Hg^{2+}$, $Pb^{2+}$ |

| **Insoluble Compounds** | | Exceptions |
|---|---|---|
| Compounds containing | $CO_3^{2-}$ | $NH_4^+$ & group IA cations |
| | $PO_4^{3-}$ | $NH_4^+$ & group IA cations |
| | $OH^-$ | group IA cations $Ca^{2+}$, $Sr^{2+}$, $Ba^{2+}$ & $NH_4^+$ |

Task: State whether the following ionic materials are soluble or insoluble in water:

| | | |
|---|---|---|
| $NaNO_3$ | $PbCl_2$ | $PbSO_4$ |
| $AgCl$ | $Ca(OH)_2$ | $AgOH$ |

The Complete ionic equation

**Recall that the state symbol (aq) means that the ions of an ionic compound are SEPARATED (dissociated) and, therefore, MOBILE when dissolved in water. Recall previous slides.**

**A complete ionic equation shows each type of ion dissolved in solution. Consider it to be a 'longhand' version of the balanced equation.**

Balanced:

$$AgNO_3\,(aq) \quad + \quad NaCl(aq) \quad \rightarrow \quad AgCl(s) \quad + \quad NaNO_3\,(aq)$$

Complete:

**Solids (s), liquids (l) and gases (g) are NOT in the (aq), state so do not appear as individual (dissociated) ions in the complete ionic equation.**

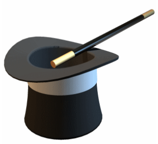
The Net ionic equation

Question: What can be done 'algebraically' with the complete ionic equation?

Complete:

$$Ag^{+}_{(aq)} + NO_3^{-}{}_{(aq)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + Na^{+}_{(aq)} + NO_3^{-}{}_{(aq)}$$

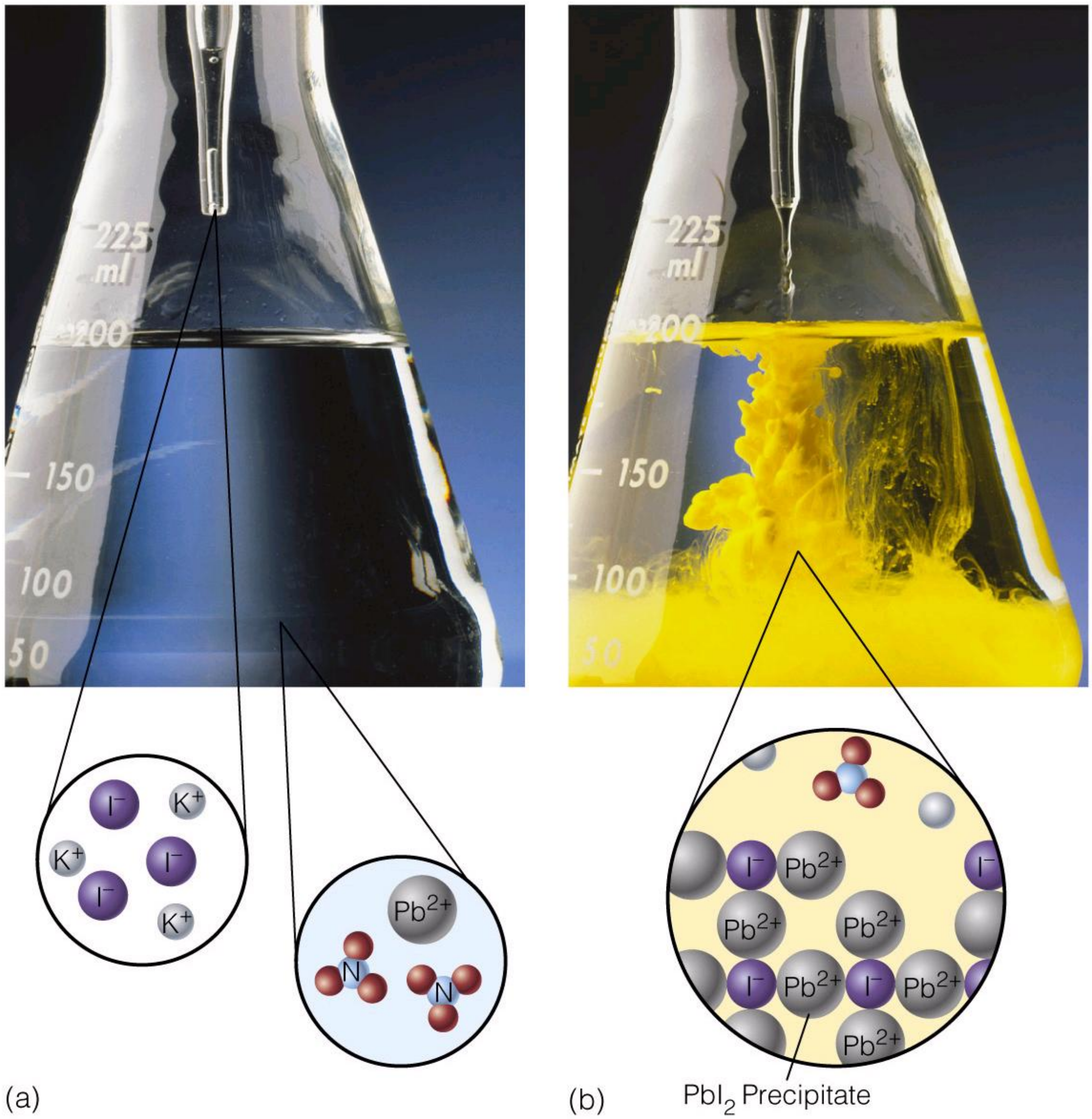
Net:



**'Cancel' ions (spectator ions) common to both sides in the Complete ionic equation to give the Net ionic equation. This is 'where the action is' in any ionic reaction.**

Walk Through: Write balanced, complete and net ionic equations for the following reaction:

1. Lead (II) nitrate solution mixed with Potassium iodide solution (use the figure or slide as a guide)


225
ml
200
150
100
50
I⁻
K⁺
Pb²⁺
N
(a)
(b)
PbI₂ Precipitate

Group Task: Write balanced, complete and net ionic equations for the following reactions:

2. Barium nitrate solution mixed with sulfuric acid solution

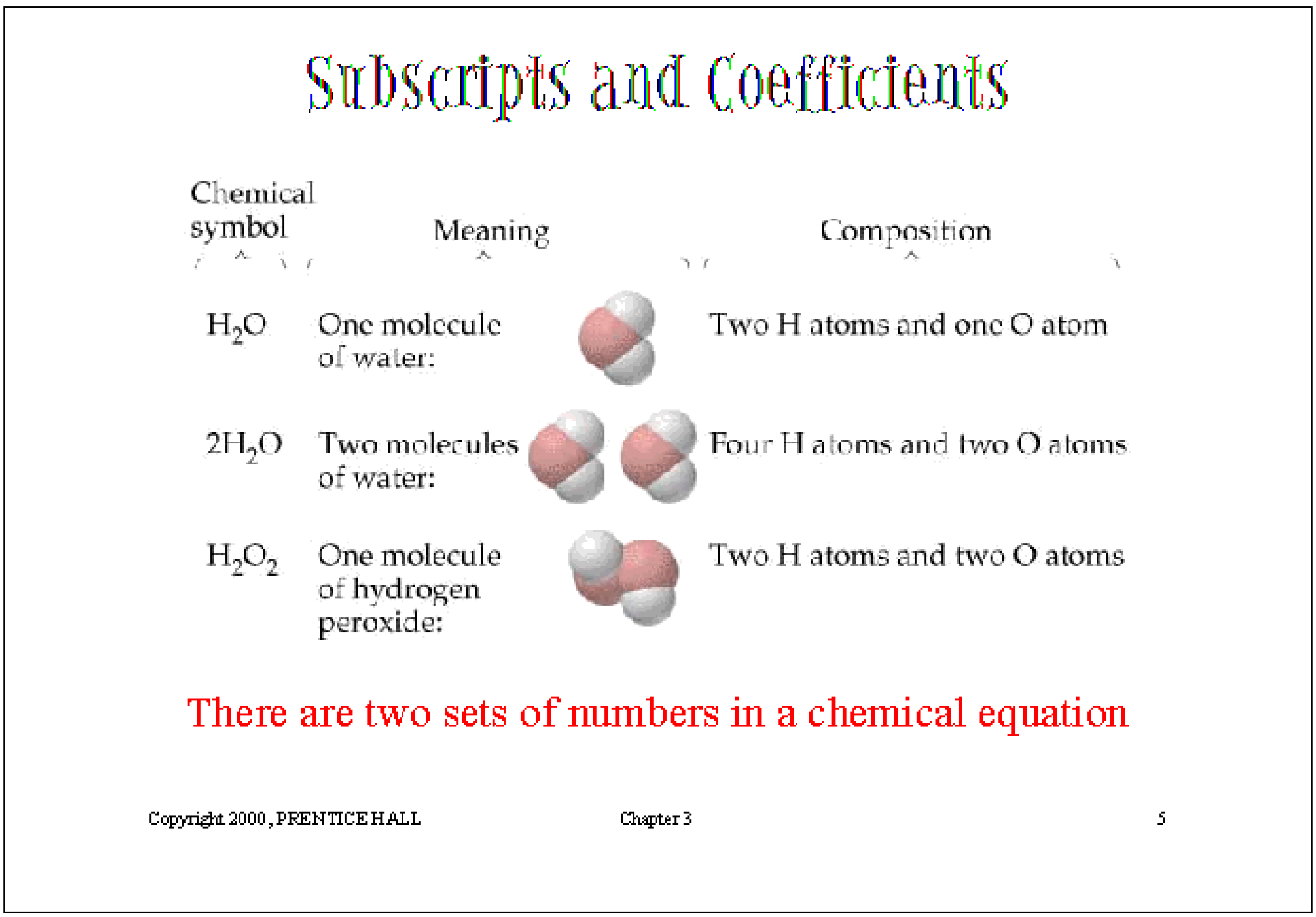
3. Sulfuric acid solution mixed with sodium hydroxide solution

4. Calcium chloride solution mixed with sodium phosphate solution (your recent lab).

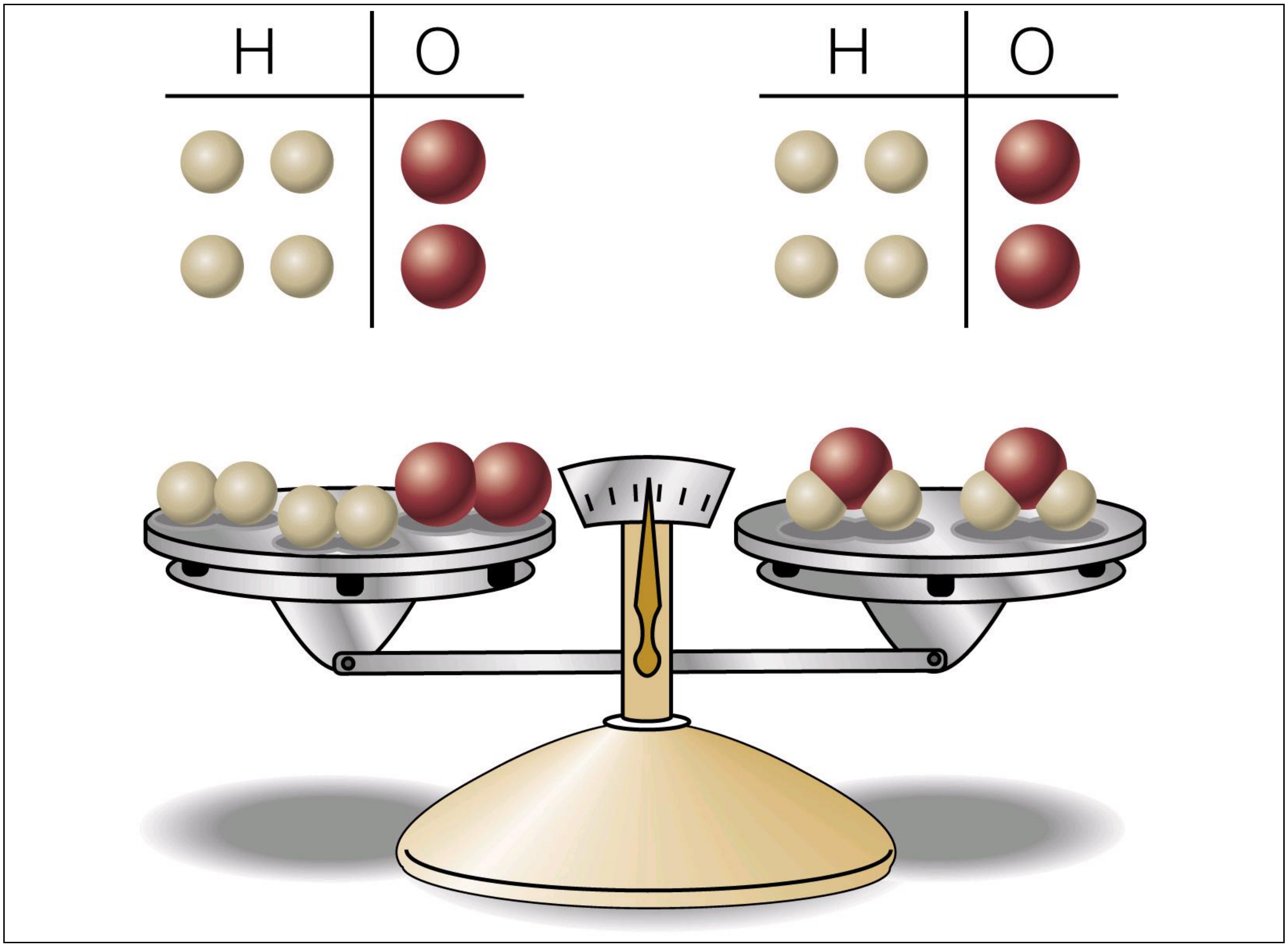
# 'Balancing Water'

<u>Draw a picture of the combustion of $H_2(g)$ process here</u>

## **Recall that…**



**In summary…**




$$2\ H_2\ (g) + 1\ O_2\ (g) \rightarrow 2\ H_2O\ (g)$$

## *“Balance” & “Those Three Equations”*

The following questions were taken from your 2nd practice midterm:

Question 3 (25 points): Write balanced chemical equations that describe the following processes. Remember to include state symbols in your equations:

a. The burning of liquid propane ($C_3H_8$ (l)) in air

b. The Neutralization of stomach acid (hydrochloric acid solution) with caustic soda (sodium hydroxide solution)

c. The reaction of solid diphosphorus pentoxide with water to form aqueous phosphoric acid

d. The decomposition of chalk ($CaCO_3$), when heated, to form solid calcium oxide and carbon dioxide gas

e. The reaction of metallic zinc with aqueous sulfuric acid to form aqueous zinc sulfate and hydrogen gas

*Extra Credit: State to which one of the five* general *classes of reaction each of the above processes belong.*

Question 4a (15 points): Write balanced, complete and net ionic equations illustrating the reaction between solutions of barium nitrate and sodium sulfate.

Question 4b (10 points): List the names and formulas of five insoluble ionic compounds containing the phosphate anion.

## *“Balance” & “Those Three Equations”*

The following questions were taken from your 2nd practice midterm:

<u>Question 3 (25 points)</u>: Write balanced chemical equations that describe the following processes. Remember to include state symbols in your equations:

a. <u>The burning of liquid propane ($C_3H_8$ (l)) in air</u>

$C_3H_8$ (l) + $5O_2$ (g) $\rightarrow$ $3CO_2$ (g) + $4H_2O$ (g)

b. <u>The Neutralization of stomach acid (hydrochloric acid solution) with caustic soda (sodium hydroxide solution)</u>

$HCl$ (aq) + $NaOH$ (aq) $\rightarrow$ $NaCl$ (aq) + $H_2O$ (l)

c. The reaction of solid diphosphorus pentoxide with water to form aqueous phosphoric acid

$P_2O_5$ (s) + $3H_2O$ (l) $\rightarrow$ 2 $H_3PO_4$ (aq)

d. <u>The decomposition of chalk ($CaCO_3$), when heated, to form solid calcium oxide and carbon dioxide gas</u>

$CaCO_3$ (s) $\rightarrow$ $CaO$ (s) + $CO_2$ (g)

e. The reaction of metallic zinc with aqueous sulfuric acid to form aqueous zinc (II) sulfate and hydrogen gas

$Zn$ (s) + $H_2SO_4$ (aq) $\rightarrow$ $ZnSO_4$ (aq) + $H_2$ (g)

*<u>Extra Credit</u>: State to which one of the five* general *classes of reaction each of the above processes belong.*

Question 4a (15 points): Write balanced, complete and net ionic equations illustrating the reaction between solutions of barium nitrate and sodium sulfate.

$Ba(NO_3)_2\ (aq) + Na_2SO_4\ (aq) \rightarrow BaSO_4\ (s) + 2NaNO_3\ (aq)$

$Ba^{2+}\ (aq) + 2NO_3^-\ (aq) + 2Na^+\ (aq) + SO_4^{2-}\ (aq) \rightarrow BaSO_4\ (s) + 2Na^+\ (aq) + 2NO_3^-\ (aq)$

$Ba^{2+}\ (aq) + SO_4^{2-}\ (aq) \rightarrow BaSO_4\ (s)$

Question 4b (10 points): List the names and formulas of five insoluble ionic compounds containing the phosphate anion.

Eg $Ca_3(PO_4)_2$ – calcium phosphate (See solubility chart)

# Chemical Composition

| | | | |
|---|---|---|---|
| Reading: | Ch 8 sections 1 - 8 | Homework: | 8.2 questions 6, 8 |
| | Ch 9 sections 1 - 5 | | 8.3 questions 10, 12, 16, 20*,22* |
| | | | 8.4 questions 28*, 30, 32*, 34, 38, 40* |
| | | | 8.6 questions 54, 56 |
| | | | 9.2 questions 8, 12, 14* |
| | | | 9.3 questions 20, 22*, 24, 26*, 30*, 32* |
| | | | 9.4 questions 46*, 48* |
| | | | 9.5 questions 60, 62* |

* = 'important' homework question

Solve the following everyday questions using 'supermarket', or (better still) 'conversion factor', math:

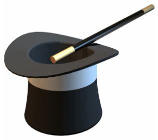
Question: If a dozen eggs weigh 1.50 pounds, then how many *dozen* eggs weigh 30.0 pounds?

Question: How many single eggs are there in 30.0 pounds of eggs?

**Solving chemistry problems that involve converting between numbers of molecules and gram weights uses EXACTLY the same concepts as the above egg problem.**

**Pounds of eggs $\leftrightarrow$ Dozens of eggs $\leftrightarrow$ Number of eggs**

The Mole



**Just like the dozen, *the MOLE is just a number that represents a bigger number*. Since atoms and/or molecules are very small (i.e. to see a collection of atoms, say in your hand, you need a lot of them), the mole is a VERY large number :**

**1 dozen = 12 things (eggs)   1 mole = $6.02 \times 10^{23}$ things (atoms)**

Task: To get an idea about how many atoms there are in a mole of atoms, write $6.02 \times 10^{23}$ as a regular number:

1 mole =______________________________________________________

Note: The mole is sometimes called **Avogadro's number ($N_A$)**, so:

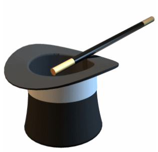

**1 mole = $N_A$ = $6.02 \times 10^{23}$ things**

Nerd stuff: When do you think *some* chemists celebrate mole day?

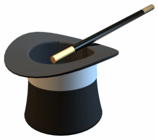
Question: If the population of the world is 5.7 billion ($5.7 \times 10^9$) people, how many moles of people is this? Hint: this is a conversion problem.

Discussion: Why is the mole ($N_A = 6.02 \times 10^{23}$) such a 'strange' number? Why not just $1 \times 10^{20}$ or something?

**&**



Task: Use the periodic table and the previous information to determine the following quantities:



Convert between grams, moles and number of atoms SEPARATELY using atomic mass values (Periodic table) and Avogadro's number respectively.

Grams $\leftrightarrow$ Moles $\leftrightarrow$ Number of atoms

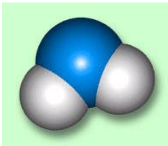
1. The *mass* of 2.0 moles of carbon atoms

2. The number of *moles* of carbon atoms in 6.0 g of C

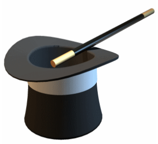
3. The *number of gold atoms* in 2.0 moles of Au

4. The number of *moles* of lead (Pb) atoms in 35.5 grams of lead.

5. The *number of Pb atoms* in 35.5 grams of lead



Question: What is the mass in amu of 1 molecule of water ($H_2O$).What is the mass of one *mole* of water molecules in grams?



**Recall that a molecule is the 'sum of its parts' (atoms). Thus, simply add the masses of all the atoms in a molecule to find the molecule's FW in amu, *OR* the mass of 1 mole of molecules (MOLAR MASS, $\mathcal{M}$) in grams. THIS IS THE POWER OF THE MOLE(!)**

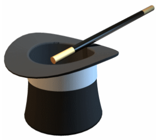
Note: The units of Molar mass ($\mathcal{M}$) are grams/mole (i.e. the number of grams in 1 mole of material).

Task: Calculate the Molar masses ($\mathcal{M}$) of the following compounds:

Carbon dioxide:

Diphosphorous pentoxide:

Calcium chloride:



**Just like with atomic masses, Molar masses can be used to convert between grams, moles and number of molecules.**

**Grams ↔ Moles ↔ Number of molecules**

Worked Example: How many molecules of sugar ($C_6H_{12}O_6$) are there in a 2.15 gram packet of sugar?

Plan: Write down what you are given and what you can immediately figure out:

Mass sugar = 2.15 g

$$\mathcal{M}_{C_6H_{12}O_6} = 6C + 12\,H + 6\,O$$
$$= 6(12.011\text{ g/mol}) + 12(1.01\text{g/mol}) + 6(16.00\text{ g/mol})$$
$$= 180.2\text{ g/mol}$$

Use the conversion factor of $\boxed{1\text{ mol } C_6H_{12}O_6 = 180.2\text{ g}}$ to find # moles sugar in 2.15 g of sugar:

$$2.15\,\cancel{\text{g}} \times \frac{1\text{mol}}{180.2\,\cancel{\text{g}}} = \underline{0.0119\text{ mols}}$$

Use the conversion factor of $\boxed{1\text{ mol} = 6.02 \times 10^{23}\text{ molecules}}$ to find # molecules of sugar in 0.0119 mols. (2.15 g) of sugar:

$$0.0119\,\cancel{\text{mol}} \times \frac{6.02 \times 10^{23}\text{ molecules}}{1\,\cancel{\text{mol}}} = \underline{7.16 \times 10^{21}\text{ molecules}}$$

**<u>Remember</u>: You CANNOT convert directly from grams to number of molecules. i.e. YOU MUST ALWAYS GO THROUGH MOLES:**

**Grams ↔ Moles ↔ Number of molecules**

Things to remember:

Key relationships:

**FW = sum of all atomic masses in a SINGLE molecular formula (amu/molecule)**

**$\mathscr{M}$ = sum of all atomic masses in any SINGLE molecular or ionic formula (grams/mole)**

$$\boxed{\mathscr{M} = \frac{\text{number grams material}}{\text{number moles of material}}}$$

**1 mole = $6.02 \times 10^{23}$ particles**

**FW and $\mathscr{M}$ have identical numerical values but DIFFERENT units**

**You can write a conversion pyramid showing the relationship between $\mathscr{M}$, g and mols!**

**The relationship between $\mathscr{M}$, #grams and #moles is THE most frequently used equations in chemistry? Why?**

Answer:

Observation(!):

<u>Task</u>: Determine the following quantities:

1. The number of *moles* of oxygen molecules in 5.0 g of oxygen gas

2. The weight *in grams* of 2.5 moles of $P_2O_5$ (s)

3. The *number* of water molecules in 330 grams of pure water

4. The mass in grams of $5.0 \times 10^{24}$ molecules of $CO_2$ (g)

## The Molar Volume

**One mole of ANY gas occupies 22.4 Liters at STP (standard temperature and pressure, 0°C, 1 atm.). This has two significant consequences:**

**1 mole = 22.4 L at STP for ANY gas**

**Gas Volume ↔ Moles ↔ Number of particles**

Task: Use the above information to determine the number of atoms of He (g) in a party balloon of volume 35.6 L (assume STP).

*Let's start the spider……*

**Applications**

A. Determining Empirical and Molecular Formulas

Recall the definitions of *molecular formula* and *empirical formula*:

**Molecular Formula**: the actual number and type of atoms in a compound, e.g. hydrogen peroxide = $H_2O_2$

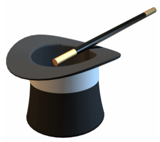
**Empirical Formula**: the lowest whole number ratio of each type of atom in a compound e.g. hydrogen peroxide = HO

Task: Complete the following table

| Name | Molecular formula | Empirical formula |
|---|---|---|
| Dinitrogen tetroxide | | |
| Benzene | $C_6H_6$ | |
| Butane | $C_4H_{10}$ | |
| Tetraphosphorous decoxide | $P_4O_{10}$ | |

Note: Empirical formulas most often pertain to molecular / covalent compounds, as ionic compounds' formulas are typically in their lowest ratio to begin with (i.e. a sample of NaCl (s) contains many more than two ions!)

Worked Example: A 1.271 g sample of Al(s) was allowed to react with chlorine. The mass of aluminum chloride produced was 6.280 g. Determine the empirical formula of aluminum chloride.



Recall that the Empirical formula is the lowest *whole number* ratio of each type of atom in a compound $\Rightarrow$ **find the moles of each type of atom and then find their ratio.**

Step 1. Write an *unbalanced* chemical equation (do not assume balancing numbers or formulas for these problems). Find the mass of the missing reactant by applying the conservation of mass law.

$$\begin{array}{ccccc} Al & + & Cl & \rightarrow & Al_xCl_y \\ 1.271\text{ g} & & & & 6.280\text{ g} \end{array}$$

Step 2. Find the *moles* of each reactant using the atomic masses from the periodic table.

Moles Al =

Moles Cl =

Step 3. Substitute the # moles determined for each type of atom in the product's empirical formula.

Al Cl

Step 4. Find the lowest whole number ratio of each type of atom in the empirical formula. This is the final answer.

Al Cl

Finding the molecular formula from the empirical formula

Recall that the molecular formula is some whole number of times larger than the empirical formula (e.g. $H_2O_2$ compared to HO (x2)).

$\Rightarrow$ **the molecular formula will be 'heavier' than the empirical formula by the same factor (x2)**

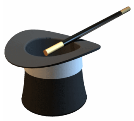
Task: Work out the molecular masses of $H_2O_2$ and HO. What is their ratio?

$\mathcal{M}_{\mathrm{H2O2}}$ = $\mathcal{M}_{\mathrm{HO}}$ =

Ratio =

Find the ratio of the molecular formula to the empirical formula – this information tells you how much 'bigger' the molecular formula is than the empirical formula.


Worked Example:  Ethylene glycol contains 38.7 % C, 9.7 % H and 51.6 % O. Calculate the empirical and molecular formula of ethylene glycol given its molar mass = 60 g/mol (60 amu/molecule)



When given the % by mass values of each atom in a compound assume a 100 g sample – the % and g values are then the same.

## B. 'Slides and Ladders' – finding theoretical yield and % yield

Important Definitions:

Theoretical Yield: The amount of product, in grams, expected (calculated) for a reaction.

Actual Yield: The amount of product, in grams, recovered (weighed) for a reaction.

% Yield :

$$\% \text{ Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

Discussion: Are theoretical and actual yields ever the same (i.e. does % yield = 100%) in practice? What factors influence the % yield?

### Finding the Theoretical Yield using 'Slides and Ladders'

Worked Example: If 5.00 g of Propane ($C_3H_8$(l)) is combusted in excess oxygen gas, what mass of water is expected to be formed? What mass and volume of $CO_2$ (g) (at STP) would you expect to collect?

Step 1. Write a balanced Chemical Equation *and*

[over]

Step 2. Set up g, $\mathcal{M}$ and mole 'ladder' grid

Step 3. Fill in the ladder grid with as much information as possible – this is typically supplied gram weights and molar mass data.

Step 4. Convert g → moles by 'climbing' down ladder(s) (g / $\mathcal{M}$ = moles).

Remember: Molar masses are calculated for **ONE** molecular formula only. I.E. ignore any balancing numbers when figuring out $\mathcal{M}$ values

Step 5. Convert moles reactant → moles product(s) by comparing balancing numbers and 'sliding' across.

Step 6. Convert moles product(s) → grams product(s) by 'climbing' up ladder(s) (moles x $\mathcal{M}$ = grams).

Note: moles of gas can be converted to Liters of gas using:

**1 mole any gas = 22.4 L at STP**

Group Tasks: Determine the following quantities

1. What mass of dissolved HCl is needed to completely react 5.00g of $CaCO_3(s)$, according to the following *unbalanced* reaction? What volume of $CO_2(g)$ is generated at STP?

   $$CaCO_3(s) + \_\_\ HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

2. What mass of magnesium oxide is recovered when 1.56 g of Mg(s) is burnt in air to give MgO(s)? What volume of oxygen gas is consumed during this process (assume STP).

3. A student recovers 1.59 g of $CaCO_3$ (s) from an experiment when they should have produced 2.32 g. What is the student's % yield for their reaction?

4. Task: Complete your lab assignment (Precipitating Calcium Phosphate), if you have not already done so

C. 'Slides and Ladders' – Limiting reactant problems

Analogy: Suppose you are making ham sandwiches. Each sandwich is made from 1 piece of ham and 2 pieces of bread:

*i.e.:* 1 ham + 2 bread → 1 sandwich

Questions:

How many sandwiches can you make from 5 pieces of ham and 18 slices of bread?

Which ingredient is there too much of (*excess, 'XS'*)?

Which ingredient is there too little of (*limiting*)?

Which ingredient ultimately determines how many sandwiches can be made? Why?

How much of the XS ingredient remains unused?

Similarly…

**Recall: Reactants ALWAYS combine in the ratio defined by their respective balancing numbers:**

$$1\ AgNO_3(aq)\ +\ 1\ NaCl(aq)\ \rightarrow 1\ AgCl(s)\ +\ 1\ NaNO_3(aq)$$

i.e. 1 mole of $AgNO_3$(aq) will react exactly with 1 mole of NaCl(aq)

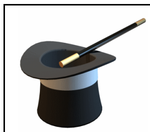
Problem: It is VERY difficult to add exactly the right ratio of reactants in the lab ⇒

**There will be too *much* of one reactant (the excess (XS) reactant)**

**There will be too *little* of one reactant (the limiting reactant)**

Discussion questions: If 10 moles of $AgNO_3$(aq) is added to 15 moles of NaCl(aq), then:

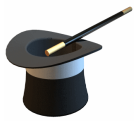
1. Which reactant is INXS?
2. Which reactant is limiting?
3. How many moles of AgCl(s) would be formed?
4. How many moles of NaCl(aq) would remain unreacted?



**Compare the 'Ideal' (from the balanced equation) and the 'Real' (given) ratio of reactants to determine which is the limiting reactant ($AgNO_3$(aq))**

**Since the LIMITING reactant will run out first, it determines the amount of product that can be formed (as well as the amount of XS reactant that is left behind)**

Questions: Work out the mass of each product formed in the following reactions, assuming 10.0 grams of each reactant are initially mixed together.



Use a regular slides and ladders approach, but 'slide' across (to find moles of product) using the molar ratio determined by the ***limiting reactant***.

Use conversions factors to find out the number of moles required to react with one of the reactants in 'NON 1:1 problems'

1. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

2. $CaCO_3(s)$ + __ $HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

## D. Concentration of Solutions

Discussion: When you finish this class chances are good you'll head out to a local bar for a well deserved 'adult beverage'. Assuming the bar you visit is running a special where you can buy a pint of beer ***or*** a pint of wine for the same price, which do you choose and why?

Answer:

**Concentration = Molarity (M) = number moles of *solute* per Liter of *solution***

i.e. Molarity = $\dfrac{\text{Moles Solute}}{\text{Liters Solution}}$ Units: mol/L or just M

Where:

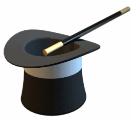
**SOLUTION = SOLUTE + SOLVENT**

Example:

**PEPSI** =

Task: Think up two more examples illustrating the components of a solution.

Question and Demo: What is the concentration of a solution made by dissolving 2.845 g of sugar ($C_6H_{12}O_6$) in water and making the final volume up to 150 mL?



**Remember that Moles, Concentration and Volume are all related for a solution. Sketch a 'triangle' to help you solve concentration problems.**

Question: What mass of NaCl is contained within 0.50 L of a 6.0 M NaCl(aq) solution?

**Since CV = moles for any solution, concentration (C) and solution volume (V) terms can also be used in 'slides and ladders' problems featuring solutions.**

<u>Example</u>: What mass of $CaCO_3(s)$ would be completely reacted with 100 mL of 2.0 M HCl? What volume of $CO_2$ (g) would be collected at STP?

$$CaCO_3(s) \quad + \quad 2\ HCl(aq) \quad \rightarrow \quad CaCl_2(aq) \quad + \quad CO_2(g) \quad + \quad H_2O(l)$$

| | | | | |
|---|---|---|---|---|
| g | C | | | |
| | V | | | |
| mol | mol | | | |

The Importance of the mole

Most of the equations we have met in this handout feature # moles as a variable. Thus, moles can in many ways be considered the chemists' link between macro and micro scale quantities.

Task: Write down as many equations you can featuring the mole. Use this information to construct a flow chart illustrating how all these conversions 'go through' moles

***"Slides and Ladders"***

The following question was taken from your 3rd practice midterm:

Question 1 (25 points): For the following *unbalanced* chemical reaction, determine the quantities listed below (Hint: balance the reaction first):

$$Fe(s) \quad + \quad O_2(g) \quad \rightarrow \quad Fe_2O_3(s)$$

A. The mass of iron (III) oxide produced when 2.56 g of solid iron is burnt in excess oxygen gas:

B. The number of oxygen molecules consumed in part (a)

Extra Credit: State to which one of the five general classes of reaction the above processes belongs.

# Gases

| | | | |
|---|---|---|---|
| Reading: | Ch 13 sections 1 - 5 | Homework: | 13.1 questions 6, 8 |
| | | | 13.2 questions 18*, 20, 24 |
| | | | 13.3 questions 30*, 34 |
| | | | 13.4 questions 42, 44 |
| | | | 13.5 questions 50*, 52*, 58, 62* |

* = ‘important’ homework question

## Background

Discussion: What do we already know about gases? Many of the concepts to be covered are based on the interpretation of ‘everyday’ experiences.

Macroscopic View:

Microscopic View:


1 atm = 760 mmHg (Torr) = 101 kPa

**The behavior of a gas can be explained in terms of:**

1. **Its VOLUME (in liters)**
2. **Its PRESSURE (most often in atm.)**
3. **Its TEMPERATURE (in Kelvin)**
4. **The number of MOLES (n) of gas present**

Understanding gases is all about understanding the relationships between the VOLUME, PRESSURE, TEMPERATURE and # MOLES (n) of a gas sample.

**The Gas Laws**

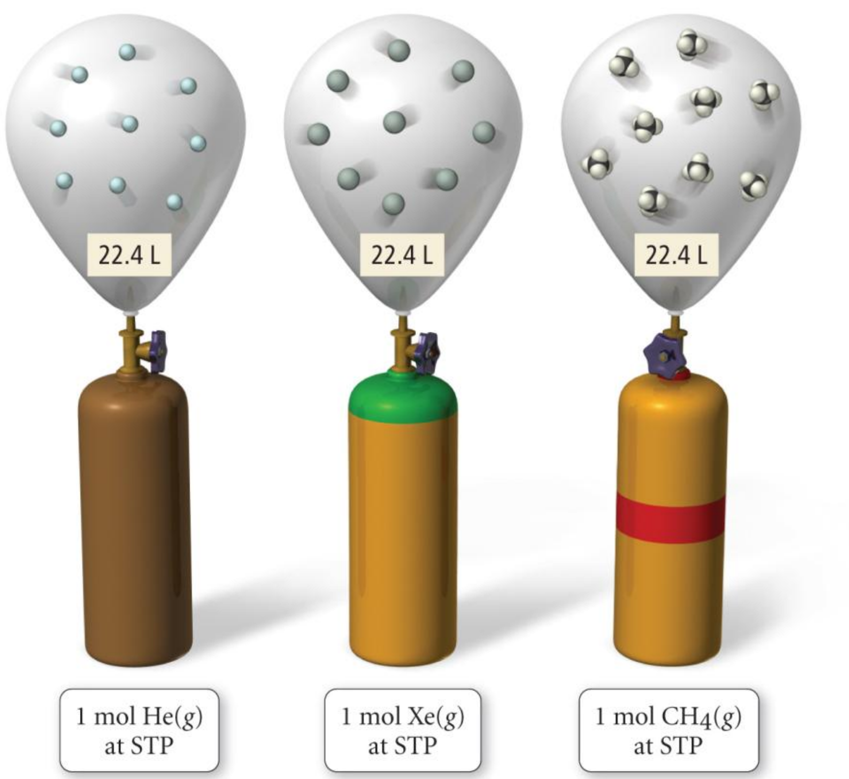
| | |
|---|---|
| Avogadro's Law: | Relationship between # **MOLES** of gas and **VOLUME** (P and T fixed) |

Everyday observation: What takes up more space, 1 mole of gas or 2 moles of gas (assume constant temp. and pressure)?

$$\mathbf{V \propto n\ (\#\ moles)}$$

**At standard temperature (273 K) and pressure (1.0 atm.), 1 mole of ANY gas occupies 22.4 L.**

**1 mole = 22.4 L at STP**

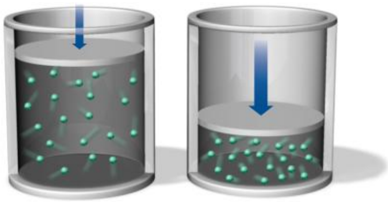


Examples:

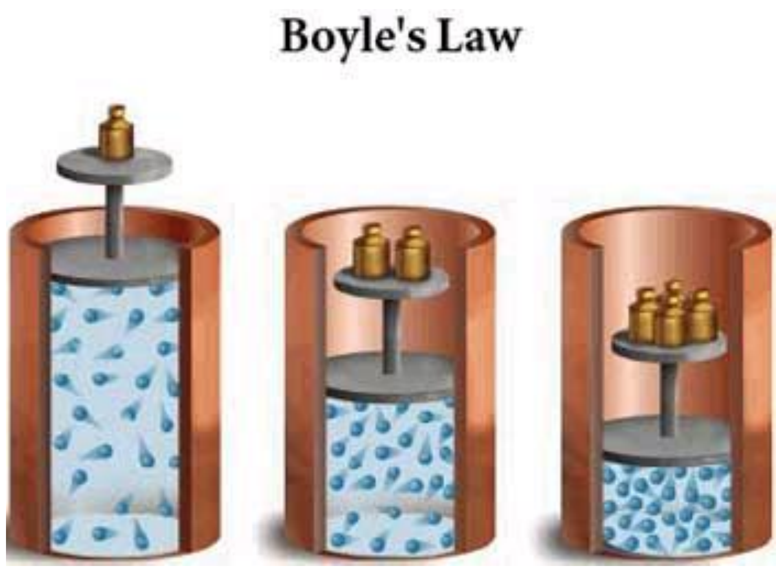
1. What volume does 3.5 moles of $H_2$ (g) occupy at STP?

2. How many atoms of He are there in a 5.0 L party balloon at STP?

| | |
|---|---|
| <u>Boyles Law</u>: | Relationship between **PRESSURE** and **VOLUME** (n and T fixed) |



<u>Everyday observation</u>: If you compress ('squeeze') the container a gas is in, does the gas pressure increase or decrease (assume fixed T and n).

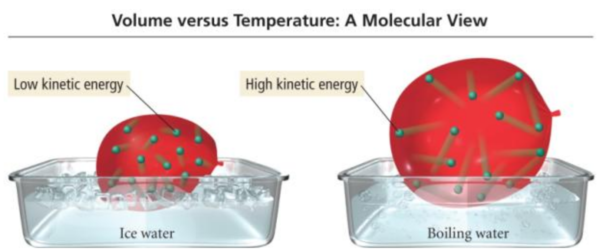


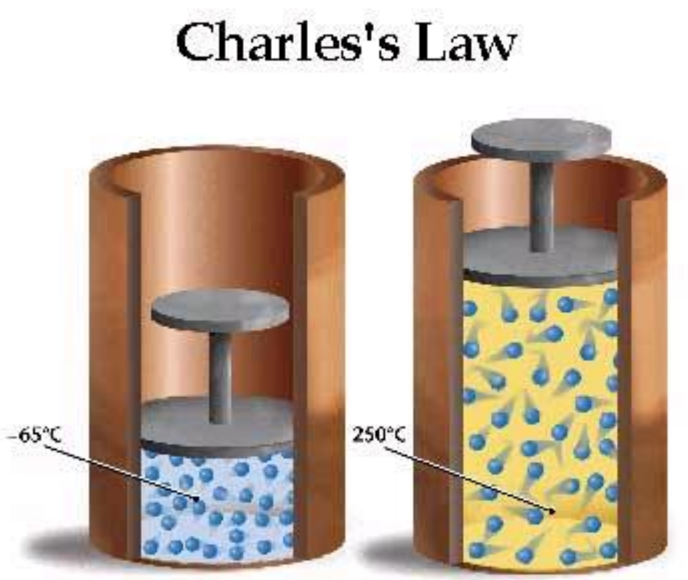

$$\mathbf{P \propto 1/V} \qquad \textit{or} \qquad \mathbf{PV = constant\ (table)}$$

<u>Example</u>: A sample of gas has a pressure of 2.0 atm. If the volume of the container the gas sample is in is decreased by a factor of 10, what is the new pressure of the gas inside? Assume T and n constant.

Charles' Law: Relationship between:
**TEMPERATURE** and **VOLUME** (n and P fixed) *or*
**TEMPERATURE** and **PRESSURE** (n and V fixed)*

Everyday observation: Why does a hot air balloon rise? What time of day is best for ballooning?




$$V \propto T$$

Example: A sample of gas occupies 12 L at 31$^o$C. What volume does it occupy at 62$^o$C? Assume P and n are constant.

**The Ideal gas Law**

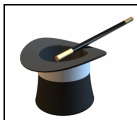
**The three gas law equations can be combined to make a new equation (the IDEAL GAS LAW) that can be used to solve ANY 'static*' gas problem**

<u>Derivation of the ideal gas law</u>

$$\mathbf{PV\ = nRT}$$

<u>Where</u>: R = 0.08206 L atm /mol K if the atm. pressure unit is used
<u>*or*</u> R = 8.314 /mol K if the Pa or N/m$^2$ pressure unit is used

<u>Example</u>: Calcium carbonate decomposes when heated to give solid calcium oxide and carbon dioxide gas. If 250 mL of $CO_2$ (g) is collected at 31$^o$C and 1.3 atm pressure, then how many moles of $CO_2$ (g) is collected?



Write down what you are given, *then* solve for the unknown quantity in 'static' problems

P =
V =
n =
R =
T =

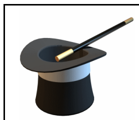
**Dynamic Problems**: changing P, V or T for a fixed number of moles of gas

<u>Derivation of the 'Dynamic' (before and after) gas law</u>

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

(before) (after)

<u>Example</u>: The pressure inside an aerosol can is 1.5 atm. at 25$^o$C. What would the pressure inside the can be at 450$^o$C? *Is there a moral to the story?*



As with the 'static' problems, write down what you are given *then* solve for the unknown quantity in 'dynamic' problems

| | |
|---|---|
| $P_1 =$ | $P_2 =$ |
| $V_1 =$ | $V_2 =$ |
| $T_1 =$ | $T_2 =$ |
| (before) | (after) |

*"Air Bag"*

The following question was taken from your 3rd practice midterm:

Question 4 (25 points): Vehicle safety 'air' bags actually inflate with nitrogen gas during collisions. If a standard car's 'air' bag has a volume of 36.0 L and inflates to a pressure of 745 Torr at 15 $^{o}$C, then:

A. How many moles of $N_2$ (g) are contained within the inflated 'air' bag described above?

B. If the car's air bag described above was instead inflated at – 20 $^{o}$C (i.e. on a Chicago winter's day), to what pressure would the 'air' bag inflate?

Extra credit: Do you think the process described in (b) would be dangerous? Explain.

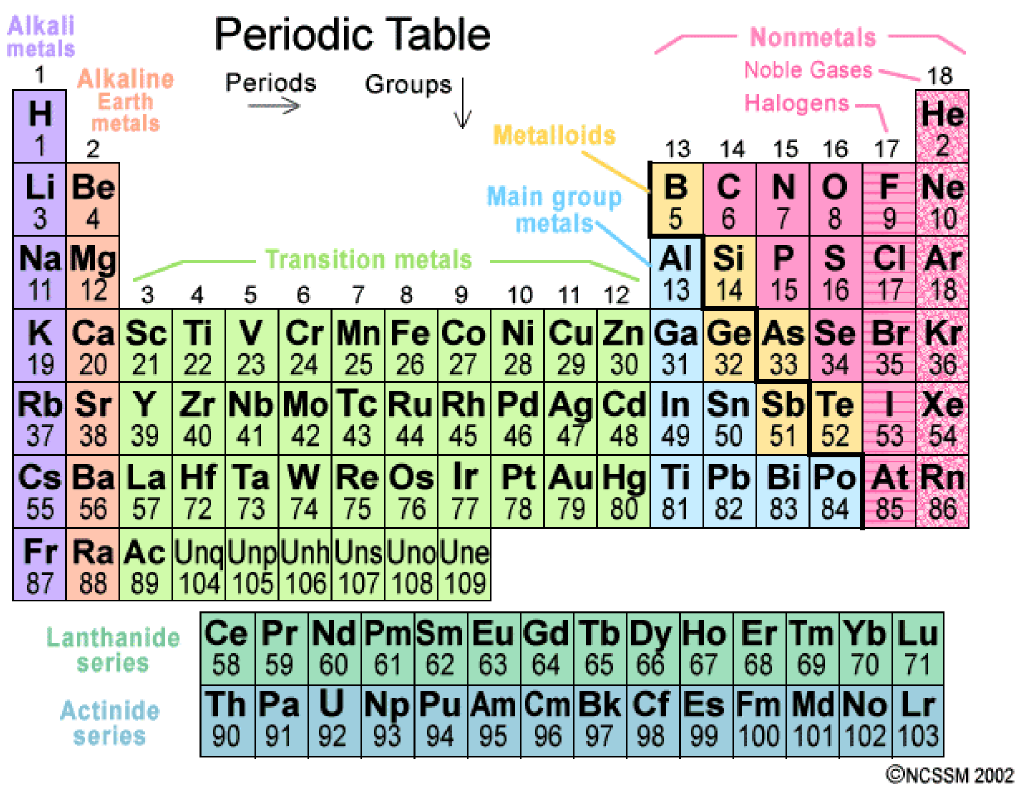
# Modern Atomic Theory – Part 1

| | | | |
|---|---|---|---|
| Reading: | Ch 12 sections 6 – 10 | Homework: | 12.6 and 12.7 questions 50, 52, 54, 56*, 58*, 60*, 62, 64*<br>12.8 questions 70*, 72<br>12.9 questions 74, 78, 80, 82*, 86* |

* = 'important' homework question

The Electronic Structure of Atoms and Molecules

Recall: What caused Mendeleev to stack certain elements in 'Family' groups?




Answer:

Macroscopic properties: Elements in the same group (column) of the periodic table have similar chemical and physical properties.

e.g. All the group II elements (the alkali earths) are all metallic, form alkali solutions when mixed with water and form +2 charge cations when ionized.

Why is this? What is the underlying microscopic 'answer' that explains these facts?

Microscopic properties: Elements in the same group (column) of the periodic table have similar outer (valence) electronic configurations.

**The loss /gain (ionic bonding), *or* the sharing (covalent bonding), of an atom's outer most electrons IS chemistry** (recall 'old' slide*)

Chemistry is 'all about' making new materials (as described by a chemical reaction's equation) – to do this *new bonds are made* (in the products) and *old bonds are broken* (in the reactants). Bond making and breaking **ONLY** involves the outer valence electrons of atoms.

Remember Dr. Mills favorite saying……

One time British soccer icon 'Gazza' with a gyro

**"Chemistry is a bit like Scottish soccer – it's basically a bunch of round things bumping into one another"**

Gazza playing out his career with Glasgow Rangers

The Electronic configurations of the first 20 elements

Seven Key fact

1.

2.

3.

4.

5.

6.

7.

<u>Important definitions</u>:

<u>Electron 'dot' symbol</u>: Includes BOTH outer (valence) AND inner (core) electrons

<u>Lewis symbol</u>: Includes outer (valence) electrons ONLY

<u>Task</u>: Draw electron 'dot' *and* Lewis symbols for:

**Si**

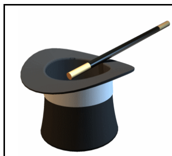
**Cl**

**P**

Add these Dot diagrams to your periodic table of electronic structure.
**Complete the table for all atom types up to Ca**

Task: Complete the following table:

| Atom | Group number | Number of valence electrons | Lewis Symbol |
|---|---|---|---|
| N | | | |
| P | | | |
| O | | | |
| S | | | |
| C | | | |
| Si  | | | |



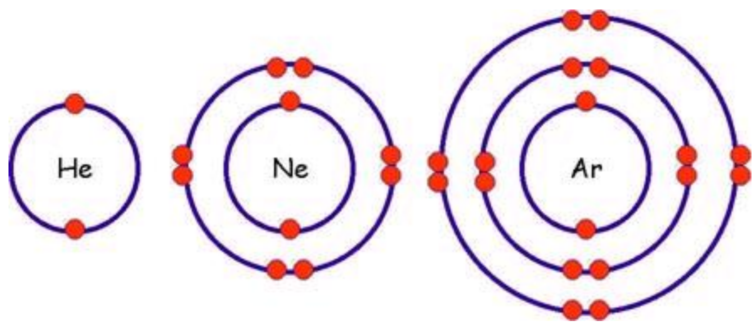
**Recall that the number of valence electrons an atom has is equal to its group number – this is why elements in the same group have similar chemical properties (similar valence configurations)**

The Octet Rule (Full Valence Shell rule)

**ATOMS WITH FULL OUTER (VALENCE) SHELLS ARE STABLE ⇒ Atoms will loose, gain or share electrons to have an inert gas (full valence shell) configuration.**

**THIS IS THE 'DRIVING' FORCE BEHIND ALL CHEMICAL PROCESSES**.

Inert gas (stable electron shell) configurations (**spot the error**!*)




Examples:

1. Ionic bonding – the formation of LiF

Recall: Ionic bonds form between atoms (metal and non-metal, which then become ions) with a large difference in electronegativity

2. Covalent bonding – the formation of $F_2$ (g)

Recall: Covalent bonds form between atoms (two non-metals) with little or no difference in electronegativity

**Simple Lewis Structures**

Overview (recall your workshop): Lewis structures are electron 'maps' of molecules, which are in turn constructed from the Lewis symbols of the molecule's component atoms.

Task: Complete the following table

| Atom | Number valence electrons | Lewis Symbol | Valencey (number of bonds formed) |
|---|---|---|---|
| C | | | |
| N | | | |
| O | | | |
| Cl | | | |
| H | | | |

**The number of bonds an atom forms in a molecule**

**≡**

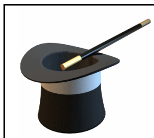
**Number of UNPAIRED valence electrons (VALENCEY) it has**

<u>EZ Lewis Symbols</u> – think of an *unpaired* valence electron as 'a hand that needs to be held' (I could not think of a more masculine analogy!). Then just have the atoms 'hold hands' (form bonds by converting unshared $e^-$ to shared pairs of $e^-$) to make the required molecule's Lewis structure. **$H_2O$ example**.

<u>Task</u>: Write formal Lewis symbols and 'EZ' Lewis symbols for the following atoms:

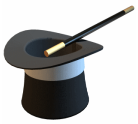
| <u>Atom</u> | <u>Formal Lewis Symbol</u>* | <u>'EZ' Lewis Symbol</u>** |
|---|---|---|
| C | | |
| N | | |
| O | | |
| Cl | | |
| H | | |

***Always write the formal Lewis symbol on a test. **This is not to be written on any formal test!**



<u>Remember</u>: Just have the atoms, as represented by 'EZ' Lewis symbols, 'hold hands' to make the required molecule's Lewis structure

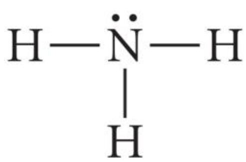
Task: Draw Lewis structures for the following molecules.



Remember: Each atom in a molecule must have as many bonds as its valencey (number of unpaired electrons). **Double or Triple bonds often arise from applying this rule**.

Note: The total number of valence electrons in a Lewis structure is simply the some of those ‘owned’ by each of the molecule’s component atoms. **Write this information next to each of the above Lewis structures**.

Ammonia ($NH_3$)



Water ($H_2O$)

Methane ($CH_4$)

Phosphorus trichoride ($PCl_3$)

Oxygen gas ($O_2$)

Nitrogen Gas ($N_2$)

Hydrogen Fluoride (HF)

Dihydrogen monosulfide ($H_2S$)

**Let’s work on your molecular modeling lab now…**

**Lewis Structures for More Complex Molecules - 'The Rules'**

**Use the following rules to figure out the Lewis structure of ANY molecule (the above are simpler examples of the application of this 'global' set of rules)**

<u>Worked Example – Carbon Dioxide ($CO_2$)</u>

1. Sum the valence electrons from all the atoms in the molecule or ion.

<u>For anions</u> (-ve), ADD one $e^-$ per negative charge on the ion
<u>For cations</u> (+ve), SUBTRACT one $e^-$ per positive charge on the ion

⇒ For $CO_2$:

2. Write the atoms on the page with the HIGHEST valencey atom in the center:

⇒ For $CO_2$:

3. Connect the outer atoms to the center atom with single lines(s) – these bonds (pair of shared electrons) are the minimum requirement for a molecule to exist.

4. Complete the valence shells of the 'outside' atoms to give them stable valence configurations.

5. Count up all the electrons in the structure and compare to the number required (from rule 1). Place any excess electrons on the center atom.

6. If the center atom does not have enough electrons for a complete valence shell, CONVERT 'OUTSIDE' LONE PAIR ELECTRONS TO DOUBLE BONDS. Remember that each outside atom's valencey must also be obeyed.

7. Double-check the valencey of all atoms and the total number of electrons in the structure.

<u>Task</u>: Follow the above rules to construct Lewis structures for the following molecules and ions:

1. $CHCl_3$
2. $CH_2O$
3. $CO_3^{2-}$

Is there more than one way to write the Lewis structure of the carbonate ($CO_3^{2-}$) ion?

**These 'different versions' of the Lewis structures are called *resonance structures*** (class demonstration)

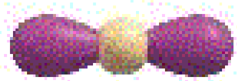
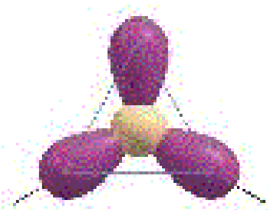
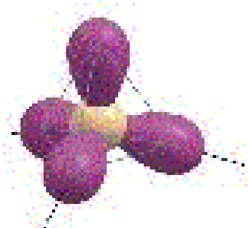
## The Shape of Molecules – VSEPR Theory

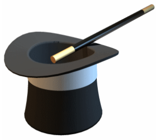
**The shape of any molecule in 3D can be determined by applying the Valence Shell Electron Pair Repulsion (VSEPR) Theory to a Lewis structure of the respective molecule**

**Electron pairs in the valence shell of a *center* atom (as drawn in a Lewis structure) *repel* one another as they have the same *negative* charge**

**The 3-D shape of a molecule is directly correlated to how the valence electron pairs are arranged in (3-D) in order to be as greatly separated from one another as possible**

**TABLE 9.1 Electron-Domain Geometries as a Function of the Number of of Electron Domains**

| Number of Electron Domains | Arrangement of Electron Domains | Electron-Domain Geometry | Predicted Bond Angles |
|---|---|---|---|
| 2 |  | Linear | 180° |
| 3 |  | Trigonal planar | 120° |
| 4 |  | Tetrahedral | 109.5° |



**Consider each electron pair (*bonded* or *lone*) as 'clumps' of negative charge**. These clumps adopt the above 3-D shapes in order to obey the VSEPR effect

Examples: Draw Lewis structures and determine the 3-D molecular shapes of carbon dioxide ($CO_2$), methanal ($CH_2O$) and methane ($CH_4$).

Molecular shape vs Electronic shape

**The *molecular* (where the atoms are) and *electronic* (where the 'clumps' of electrons are) shapes of molecules are often different**

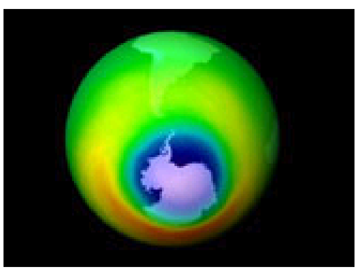
**Recall: The valence electron pairs' (bonded *and* lone) determine the overall *electronic shape* of the molecule**

**But: The positions of the molecule's atoms *relative to one another* (after the electronic shape has been fixed) determine the *molecular shape***

Examples: Draw Lewis structures and determine the 3-D molecular and electronic shapes of methane ($CH_4$), water ($H_2O$) and ammonia ($NH_3$).

Question of the week: Draw Lewis structure(s) for the ozone molecule ($O_3$) and determine its molecular shape using VSEPR theory.

Environmental Concerns

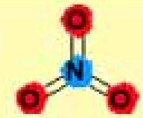
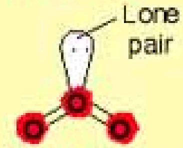
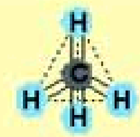
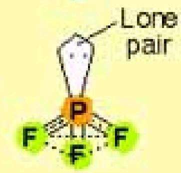
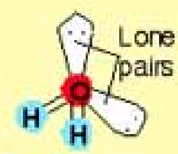


The Ozone ‘hole’ over Antarctica


An Ozone action day sign warning of ***excess*** $O_3$

Discussion: How can there simultaneously be *too much* (ozone action days) and *too little* (Antarctica’s ozone ‘hole’) ozone in the atmosphere? Solution?

<u>The relationship between molecular shape, electronic shape, numbers of bonding electron pairs and lone pairs of valence electrons</u>

| Electron Groups | | | Arrangement of Groups | Molecular Shape | Example | |
|---|---|---|---|---|---|---|
| Total | Bonding | Lone | | | | |
| 2 | 2 | 0 | Linear | Linear | $CO_2$ |  |
| 3 | 3 | 0 | Trigonal planar | Trigonal planar | $NO_3^-$ |  |
| | 2 | 1 | | Bent (or angular) | $O_3$ |   |
| 4 | 4 | 0 | Tetrahedral | Tetrahedral | $CH_4$ |  |
| | 3 | 1 | | Trigonal pyramidal | $PF_3$ |   |
| | 2 | 2 | | Bent (or angular) | $H_2O$ |   |

## “Lewis”

The following question was taken from your 3rd practice midterm:

Question 3a (20 points): Draw Lewis structure(s) for the $CO_3^{2-}$ anion, ***include all possible resonance form(s)***.

Question 3a (5 points): Use VSEPR theory to predict the electronic and molecular shape of the carbonate ($CO_3^{2-}$) anion.

Electronic shape:

Molecular shape:

# Modern Atomic Theory – Part 2

| | | | |
|---|---|---|---|
| Reading: | Ch 11 sections 5 - 10 | Homework: | 11.7 questions 30, 32*, 36*<br>11.8 questions 44<br>11.9 questions 50*, 52*, 54*<br>11.10 questions 58, 60*, 62 |

* = 'important' homework question

## Modern View of the Electronic Structure of Atoms – 'Wave' Models


**Erwin Schrödinger, as seen on a one thousand schilling Austrian bank note in the late 1930's.**

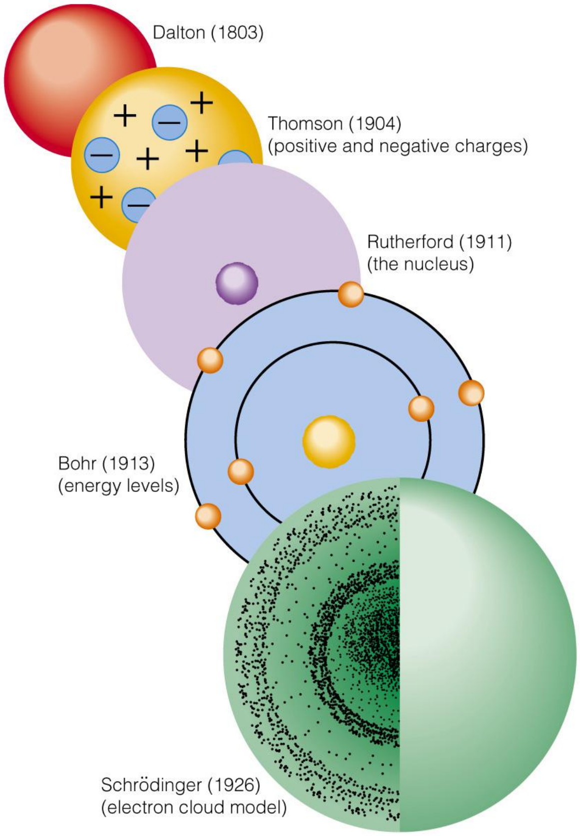
**Background: The turn of the 20th century was a golden era for the physical sciences. Einstein was working towards the theory of special relativity (and was receiving *all* the attention), while Erwin Schrödinger was quietly 'turning the science on its head' by redefining how scientists fundamentally think about matter, particularly 'small' particles, such as electrons.**

"So, you are telling me electrons aren't particles anymore?"

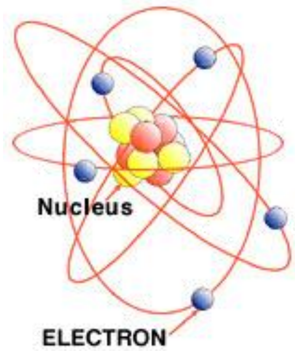
Schrödinger's great genius was devising a form of math that explained the behavior of electrons (or any other 'small particle') in terms of WAVE, rather than PARTICLE, math. We will use the results of this 'wave' math (quantum mechanics) ***not*** figure it out (very hard!)

**Instead of electrons 'orbiting' a nucleus (PARTICLE MODEL), they are now known to exist as waves in diffuse clouds around the nucleus (WAVE MODEL).**

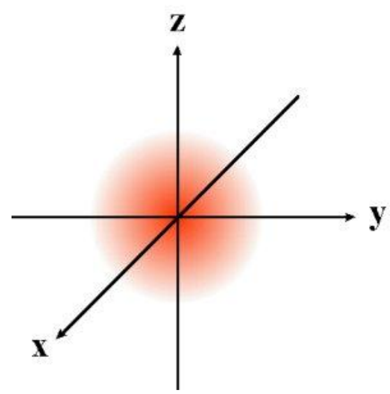
*Got proof?? Yes!*




Evolution of the wave model of electron behavior




Classical (particle) model of a boron atom




Electron density map (wave) model of a hydrogen atom

The Power of the Schrödinger Equation (‘wave’ math)

**Solving the Schrödinger equation for valence electrons tells you their position and energy (i.e. everything about them). You can then determine their interactions with one another**

****THIS IS CHEMISTRY****

**We will use the RESULTS* from such calculations in order to better understand atomic structure (i.e. where electrons are located in atoms)**

*ask me to tell you a scary story from grad. school!

The Schrödinger Equation (the new ‘wave’ math – celebrated by nerds the world over)

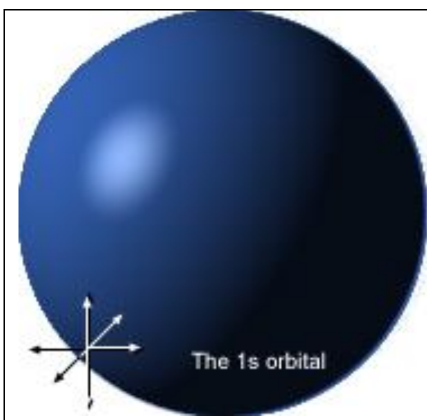


The Schrödinger equation, as seen on his and hers ‘nerd’ T shirts at Star Trek Conventions, Physics conferences etc.(left and above). Hard core ‘Trekies’ (right)

Comparison of Dot and Electronic orbital diagrams

**<u>Recap</u>: In the 1920’s it was shown (mathematically) that the electrons exist as *waves* in discrete, uniquely shaped ‘clouds’ called orbitals.** Thus ‘dot’ and Lewis models we have been using are *empirical*, in other words early chemists knew they worked, but were not sure why**. The new math (called quantum mechanics) changed all that…..**

**The FIRST two electrons in *every* shell (each row in the periodic table) ‘live’ in a spherical ‘cloud’ called an ‘s’ orbital**




**<u>Example</u>: Hydrogen is in the first row of the periodic table and has 1 electron - its electron is said to be in the ‘1s’ orbital of the first shell.**

Hydrogen has 1 electron, so has the electronic configuration:

H : $1s^1$

Important: the superscript ‘1’ is not a mathematical power, it just says how many electrons are in the orbital.

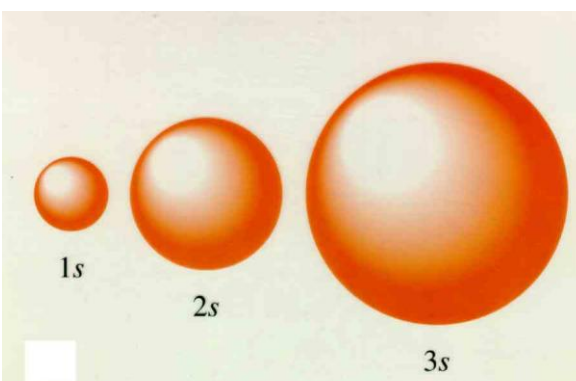
Example: Sketch a 'dot' and modern orbital diagram illustrating the electronic structure of He.

Dot symbol Orbital sketch

**There can be a maximum of 2 electrons per orbital ('cloud'),** *this is why there are only 2 elements in row 1 of the periodic table* - H and He have a single 1s orbital (which can hold a max. of 2 electrons).

**The FIRST and SECOND electrons in shells 2 and 3 (rows 2 and 3 in the periodic table) of elements 'live' in a spherical 's' clouds (sub shells) too – 2s and 3s respectively.**

The further the shell is from the nucleus, the larger it is (like blowing up a balloon, they 'inflate')



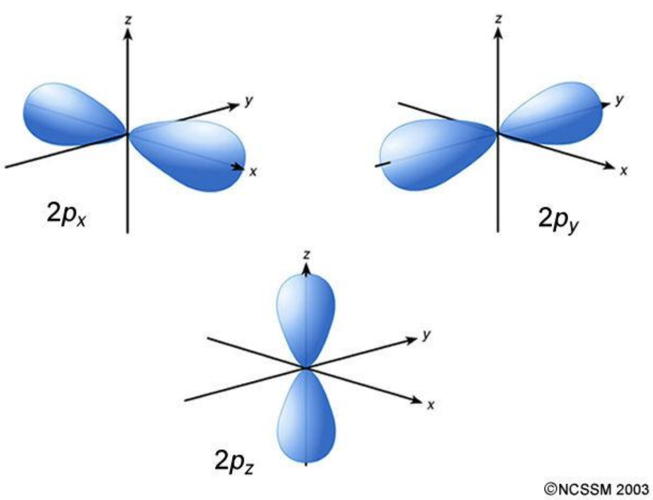

Comparison of the 1s, 2s and 3s sub shells. Recall that even though the 'clouds' (orbitals) become larger, each can still hold a maximum of only 2 electrons.

Problem: The second and third rows of the periodic table have 8 elements, so they must have orbitals that can hold up to 8 electrons. Can an 's' orbital hold 8 electrons?

Answer and conclusion:

**The THIRD - EIGHGTH electrons in shells 2 and 3 (rows 2 and 3 in the periodic table) 'live' in a dumbbell shaped 'clouds' (sub shells) called 'p' orbitals.**

Recall: there can be a max. of 2 electrons per 'cloud' (orbital), so since there are 8 elements in rows 2 and 3, *these shells must contain one 's' and three 'p' sub shells* (1 x 2 electrons & 3 x 2 electrons per orbital respectively)




Since there can **only** be 2 $e^-$ per orbital, and there are 6 more elements (therefore 6 more electrons) beyond the 2 $e^-$ in the 's' orbital, there must be three more 'p' orbitals in each shell.

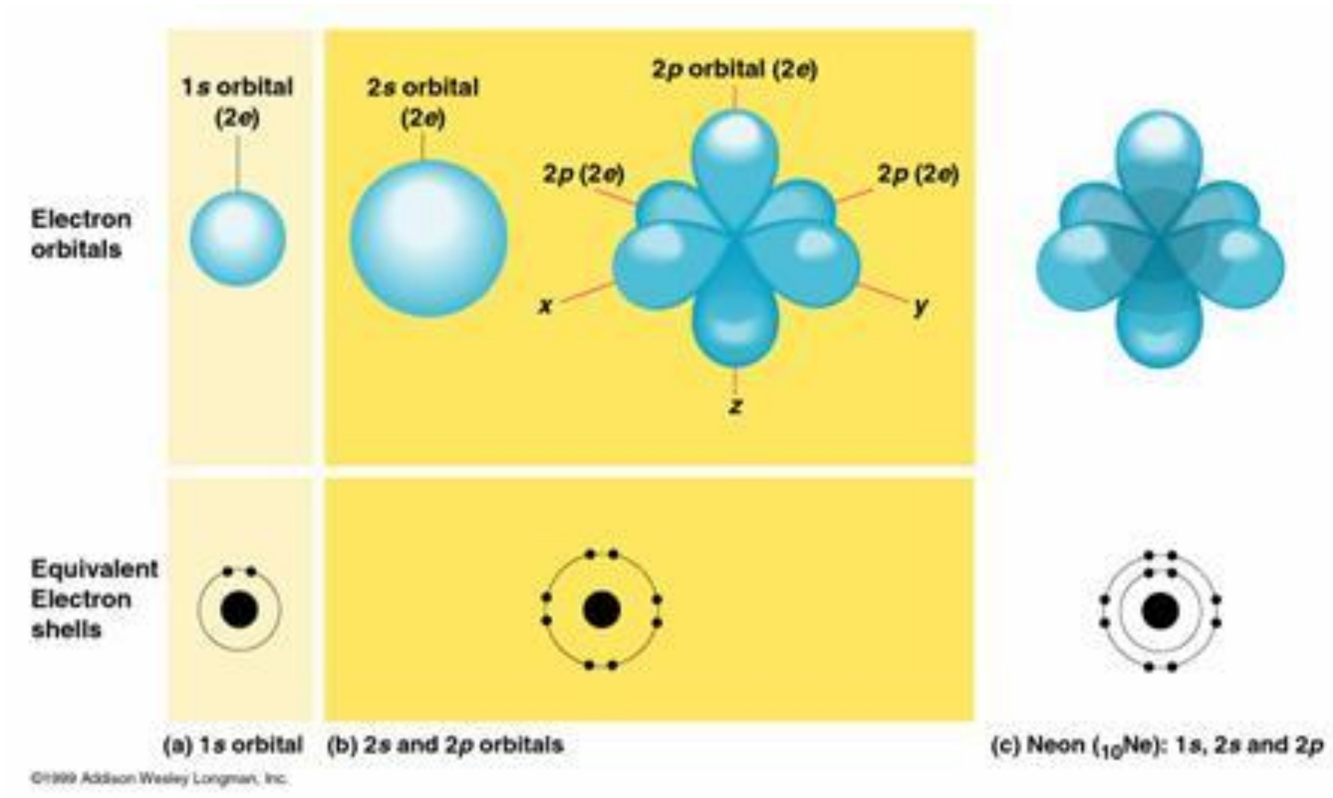
Fact: There are $p_x$, $p_y$ and $p_z$ orbitals – these make up the p *sub shell*

Nitrogen has the electronic configuration:

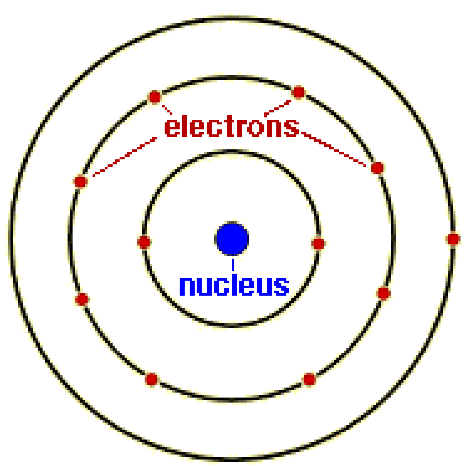
**N: $1s^2 2s^2 2p^3$**

The three 2p orbitals shown together:

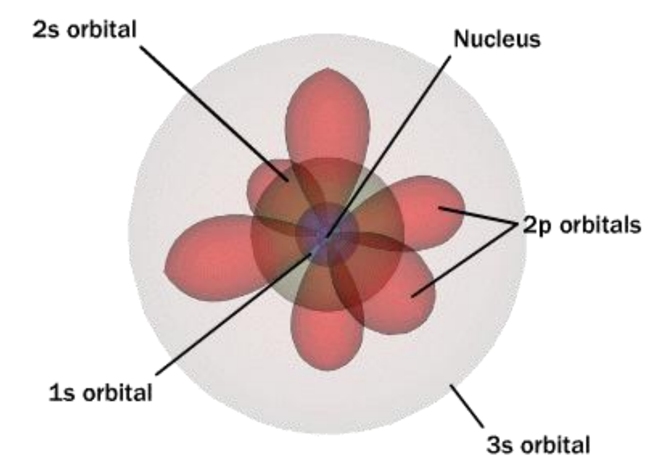
Overview comparison between dot and orbital models:




Side by Side Comparison of the Two Types of Model




Particle model

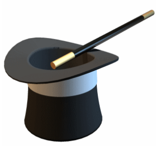



Wave Model

Task: Sketch ‘dot’ and modern orbital diagrams illustrating the electronic structure of Oxygen.

Dot symbol

Orbital sketch



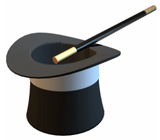
**Think of orbitals as empty parking spaces in a very large parking lot** (like at Dodger stadium). An atom has a fixed number of electrons (‘cars’), which fill these spots, starting closest to the nucleus.

Each atom has the same large parking lot, it’s just the number of filled spots that change for each atom. The location of each space can be determined mathematically by solving the Schrödinger Equation

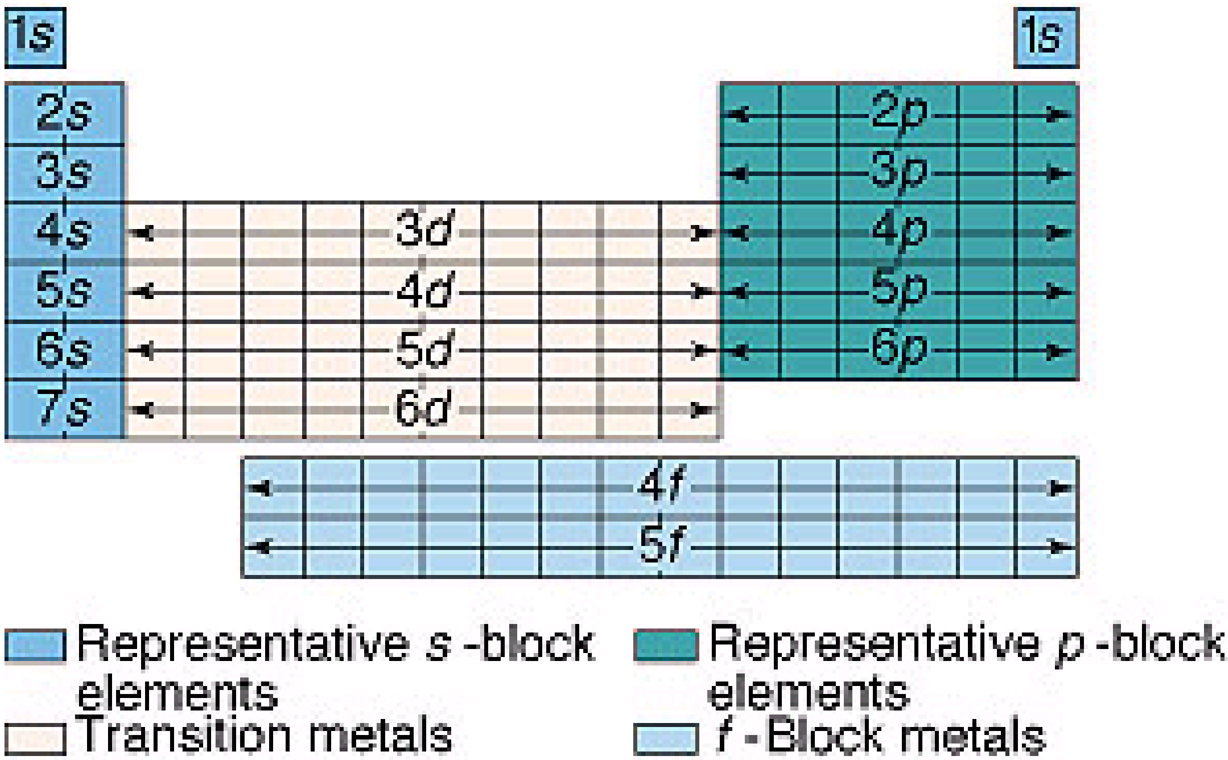
Dodger Stadium and its parking lot


The Dodger Stadium parking lot

## Writing Electronic Configurations



***'Read across'* the period table while applying the filling of orbitals rules (i.e. 'parking electrons') to obtain the electronic configuration of *any* element. This methodology is illustrated in the following version of the periodic table:**




The order of filling orbitals is:

$$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ .......$$

Task: Complete the above filling scheme up to the element with its last 3 electrons in the 5p orbital. Which element is this?

Aside: Ever wondered why elements in columns 1 and 2 are called the 's' block elements and those in columns 3 – 8 the 'p' block elements? It's because *that* sub shell is the ***last*** one 'being filled' during the processes of assigning electron addresses ('parking spaces').

Task: Write electronic configurations for Li, Na, C and Si. Do you notice anything familiar about the number of electrons in each atom's valence shell?

Li: C:

Na: Si:

Answer:

Note: Since the valence electrons are of most interest, electronic configurations are often abbreviated using [He], [Ne] etc. to represent the appropriate core configuration.

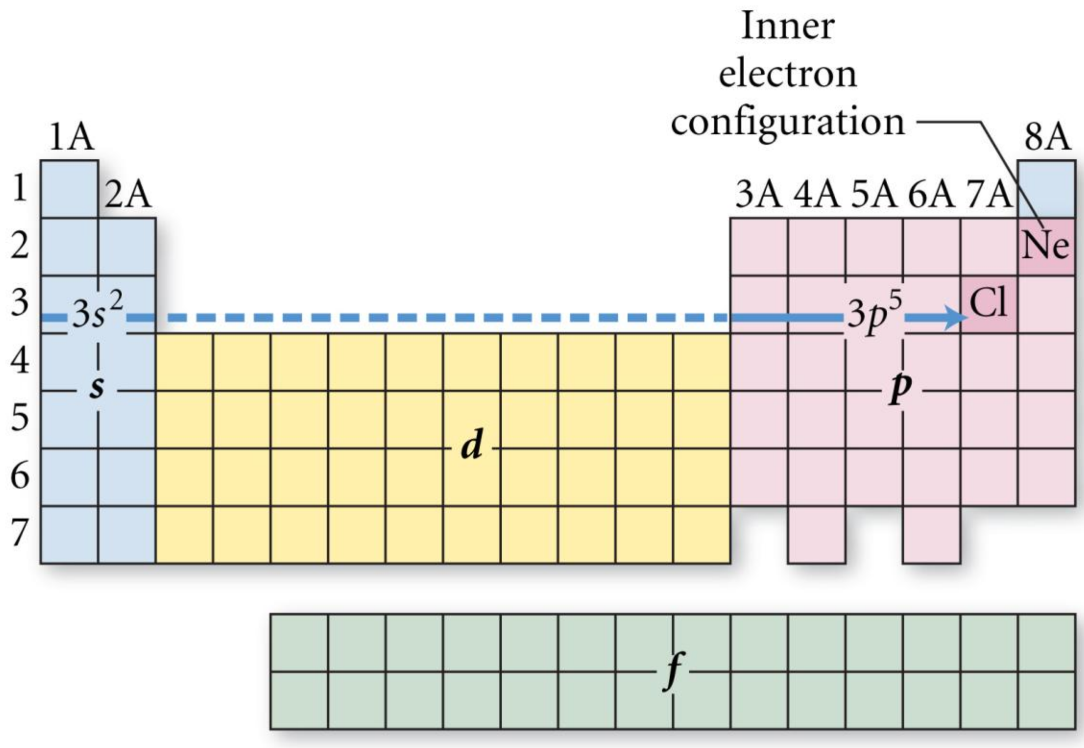
Electronic configurations of Chlorine

'Standard'

Cl:

'Abbreviated'

Cl:




<u>Wrap up</u>: Determine the following atoms' electronic configurations of the by 'reading across' the periodic table

Li: *or* Li:

Al: *or* Al:

Xe: *or* Xe:

Orbital Diagrams:

Electronic configurations can also be written as orbital ‘box’ diagrams

**Each orbital (which can contain up to 2 electrons, recall) is represented by a box.**

**Degenerate orbitals (e.g. 2p, 3d orbitals, which just differ in ‘direction’) are written as connected boxes.**

The order of filling orbitals – a comparison of styles

Electronic configuration:

**X: $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$** …..

Equivalent orbital ‘box’ diagram:

**X:**

Example: Draw an orbital box diagram for Fe*

**Fe:**

Task: Write electronic configurations, orbital box diagrams, *and* draw 'old style' dot diagrams illustrating the electronic structure of:

| | Electronic configuration | 'Orbital' box diagram | Dot diagram |
|---|---|---|---|
| Li | | | |
| N | | | |
| F | | | |
| Na | | | |
| P | | | |
| Cl | | | |

*“Electron addresses”*

The following question was taken from your 3rd practice midterm:

Draw *Lewis symbols* and *‘Dot’ structures* for the following:

| Atom or Ion | Lewis Symbol | Dot Structure |
|---|---|---|
| C | | |
| $O^{2-}$ | | |

Draw *orbital ‘box’ diagrams* and write *electronic configurations* for the following atoms and ion:

## Carbon atom

Orbital ‘box’ diagram:

Electronic Configuration:

## Oxide *anion*

Orbital ‘box’ diagram:

Electronic Configuration:

## Sodium atom

Orbital ‘box’ diagram:

Electronic Configuration:

# Chemical Bonding and Periodic Trends

| | | | |
|---|---|---|---|
| Reading: | Ch 12 sections 1 – 4 | Homework: | 12.1 questions 4, 6 |
| | Ch 11 section 11 | | 12.2 questions 8, 10, 12*, 14*, 16 |
| | | | 12.3 questions 24, 26, 28 |
| | | | 11.11 questions 74, 76*, 80*, 82* |

* = 'important' homework question

Discussion: In simple terms, what is a chemical bond? What does a chemical bond do?

Recall: From *Modern Atomic Theory 1* we know there are two general types of bond – IONIC and COVALENT

Ionic bonds – form due to a ***large*** difference in electronegativity between the bonding atoms (which subsequently form ions via ***electron transfer***)

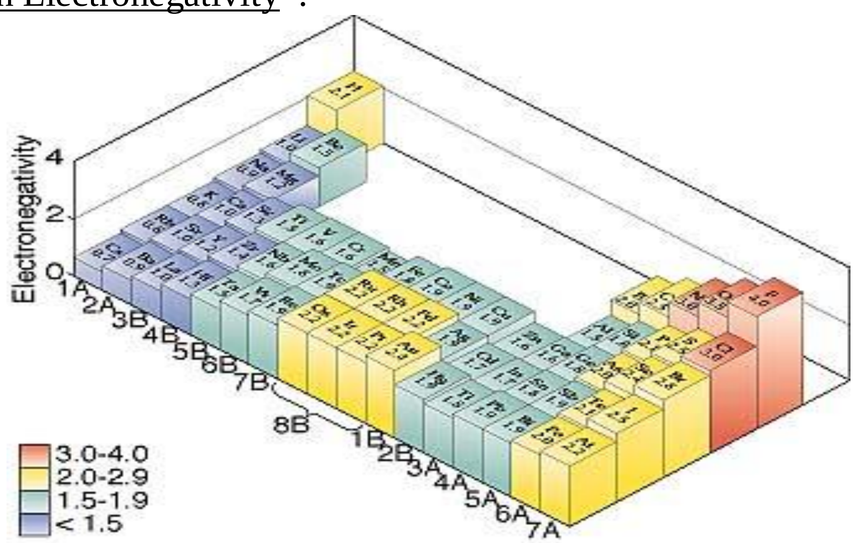
Generic

Lithium Fluoride

Recall that ELECTRONEGATIVITY is the ability of an atom to ***attract*** **electrons.**

**The trend is *low* (metal, left of p. table, electrons easily lost) → *high* (non-metals, right of p. table, electrons more greatly attracted)**

<u>Trends in Electronegativity</u>*:




***Electronegativity is not a true atomic property – it is a derived mathematically from other atomic properties (see later)**

<u>Covalent bonds</u> – form due to a ***low*** difference in electronegativity between the bonding atoms (which subsequently ***share a pair of electrons***)

<u>Examples</u>: $H_2$ (slide),$F_2$ (both have *pure* covalent bonds – no difference in electronegativity)

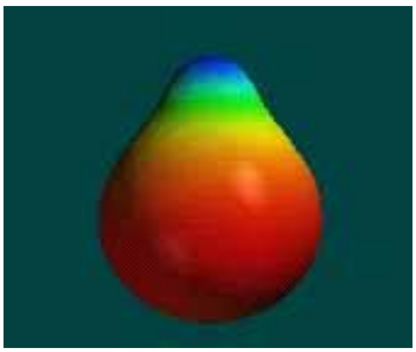
<u>Recall</u>: the driving force behind the formation of covalent (and ionic) bonds is the formation of a full valence shell.

Polar Covalent Bonds - are a *mixture of ionic and pure covalent bonding types*. The electrons are shared (as in a covalent bond) but are drawn closer to the more electronegative atom (as in an ionic bond)

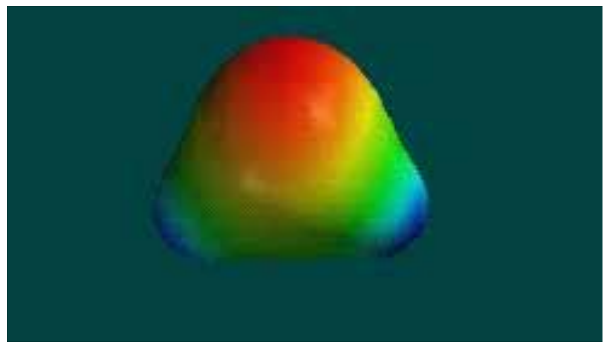
**The atoms involved in POLAR covalent bonds are typically BOTH non-metals, but ALSO have a large difference in electronegativity.**

Common examples of polar covalent bonds are H-F and H-O

Examples: H-F and $H_2O$



Electron density map of HF



Electron density map of $H_2O$

Molecules with dipoles

**Polar covalent bonds create a separation of charge in the respective molecule**

Such a separation of charge is known as a dipole. Molecular dipoles are represented by an arrow with a '+' at the positive end of the molecule

Task: Sketch diagrams of HF and $H_2O$ that show their respective molecular dipoles (slide)

## Electronegativity Values

**Viewing:Electronegativity**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 H 2.20 | | | | | | | | | | | | | | | | | 2 He 0 |
| 2 | 3 Li 0.98 | 4 Be 1.57 | | | | | | | | | | | 5 B 2.04 | 6 C 2.55 | 7 N 3.04 | 8 O 3.44 | 9 F 3.98 | 10 Ne 0 |
| 3 | 11 Na 0.93 | 12 Mg 1.31 | | | | | | | | | | | 13 Al 1.50 | 14 Si 1.80 | 15 P 2.19 | 16 S 2.58 | 17 Cl 3.16 | 18 Ar 0 |
| 4 | 19 K 0.82 | 20 Ca 1.00 | 21 Sc 1.36 | 22 Ti 1.54 | 23 V 1.63 | 24 Cr 1.66 | 25 Mn 1.55 | 26 Fe 1.83 | 27 Co 1.88 | 28 Ni 1.91 | 29 Cu 1.90 | 30 Zn 1.65 | 31 Ga 1.81 | 32 Ge 2.01 | 33 As 2.18 | 34 Se 2.55 | 35 Br 2.96 | 36 Kr 0 |
| 5 | 37 Rb 0.82 | 38 Sr 0.95 | 39 Y 1.22 | 40 Zr 1.33 | 41 Nb 1.6 | 42 Mo 2.16 | 43 Tc 1.9 | 44 Ru 2.2 | 45 Rh 2.28 | 46 Pd 2.20 | 47 Ag 1.93 | 48 Cd 1.69 | 49 In 1.78 | 50 Sn 1.96 | 51 Sb 2.05 | 52 Te 2.1 | 53 I 2.66 | 54 Xe 0 |
| 6 | 55 Cs 0.79 | 56 Ba 0.89 | 57 La 1.10 | 72 Hf 1.3 | 73 Ta 1.5 | 74 W 2.36 | 75 Re 1.9 | 76 Os 2.2 | 77 Ir 2.20 | 78 Pt 2.28 | 79 Au 2.54 | 80 Hg 2.00 | 81 Tl 2.04 | 82 Pb 2.33 | 83 Bi 2.02 | 84 Po 2.0 | 85 At 2.2 | 86 Rn 0 |
| 7 | 87 Fr 0.7 | 88 Ra 0.9 | 89 Ac 1.1 | 104 Rf -- | 105 Ha -- | 106 Sg -- | 107 Ns -- | 108 Hs -- | 109 Mt -- | 110 Unn -- | 111 Unu -- | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lanthanide Series | 58 Ce 1.12 | 59 Pr 1.13 | 60 Nd 1.14 | 61 Pm 1.13 | 62 Sm 1.17 | 63 Eu 1.2 | 64 Gd 1.20 | 65 Tb 1.2 | 66 Dy 1.22 | 67 Ho 1.23 | 68 Er 1.24 | 69 Tm 1.25 | 70 Yb 1.1 | 71 Lu 1.27 |
| Actinide Series | 90 Th 1.3 | 91 Pa 1.5 | 92 U 1.38 | 93 Np 1.36 | 94 Pu 1.28 | 95 Am 1.3 | 96 Cm 1.3 | 97 Bk 1.3 | 98 Cf 1.3 | 99 Es 1.3 | 100 Fm 1.3 | 101 Md 1.3 | 102 No 1.3 | 103 Lr -- |

Discussion: Do you think that electronegativity values are determined experimentally or calculated? Look at the values presented in the above table to help make your decision. How can electronegativity *differences* between atoms be determined? How does this relate to bond type?

Electronegativity values for ***most*** atoms are known – they are calculated from a variety of atomic properties, including nuclear charge and atomic radius (see next section)

The type of bond that exists between two atoms depends on the respective atoms' *difference* in electronegativity

<u>'Ball Park' determination of bond type (based on electronegativity differences)</u>

| Δ Electronegativity | Bond Type |
|---|---|
| $0 \rightarrow 0.2$ ('small') | Covalent |
| $0.3 \rightarrow 1.6$ ('medium') | Polar Covalent |
| $1.7 \rightarrow 3.3$ ('large') | Ionic |

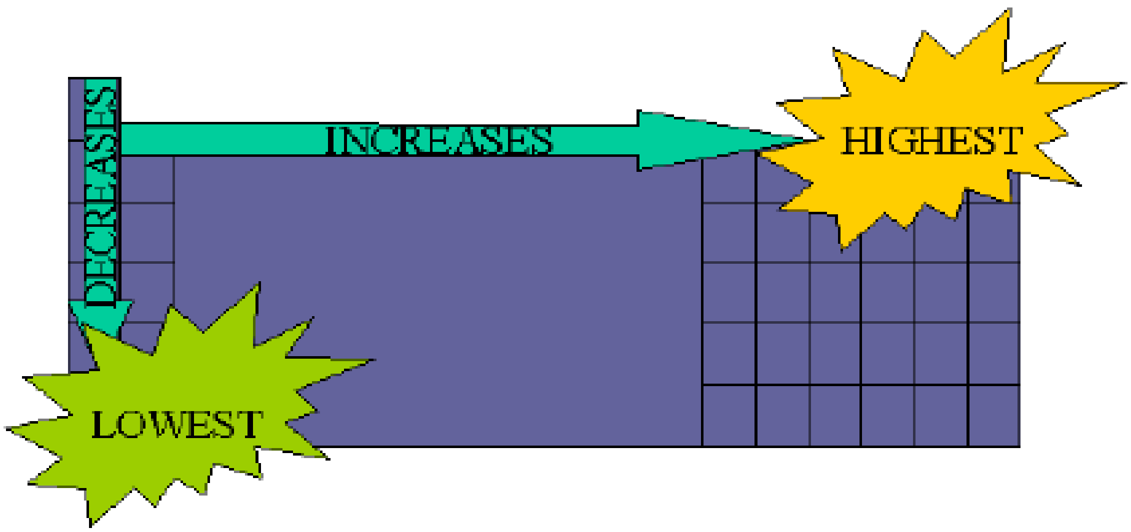
<u>Task</u>: Determine the type of chemical bond that exists between the following pairs of atoms

| Bonded atoms | Δ Electronegativity | Type of bond |
|---|---|---|
| H-Cl | | |
| Cl-Br | | |
| Na-F | | |
| N-O | | |
| C-O | | |

## The Origins of Electronegativity – 'True' Atomic Properties

**As with electronegativity, essentially all other periodic trends follow the same general 'bottom left to top right' scheme. This is because electronegativity is determined from these 'true' atomic properties.** See generic diagram the below. The periodic trends examined will be:

**Atomic Size (radius)** **$1^{st}$ Ionization Energy**



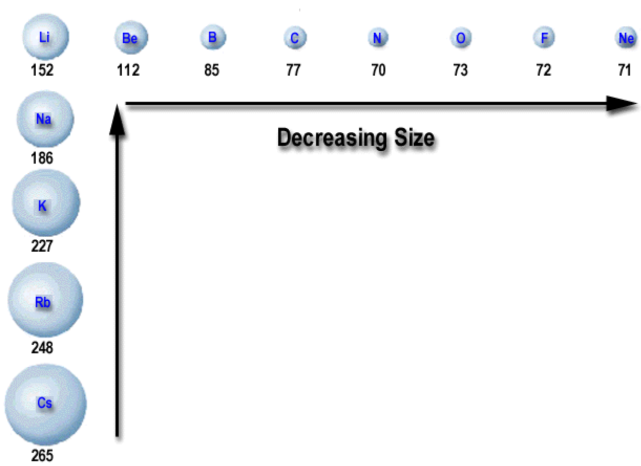

### Atomic Radius

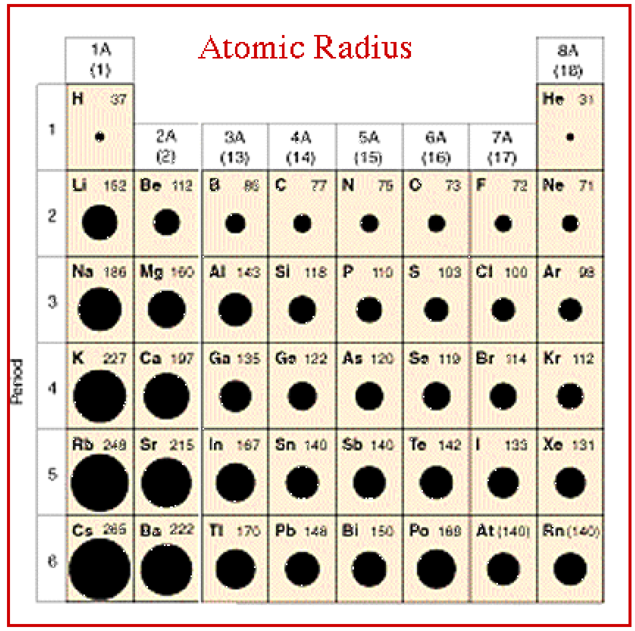
<u>Discussion</u>: How do trends in the size (radius) of atoms 'across a row' and 'down a column' in the periodic table vary? Use the following figures as a guide. Why do you think this is so?

| |
|---|
| 1. 'Across a Row' |

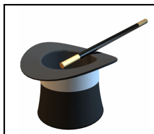
| |
|---|
| 2. 'Down a Column' |

## Atomic Radius Trends



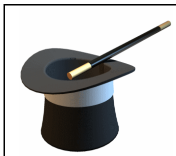




Trends and established values (pm) of atomic radii for various elements



**Recall: The atomic radii of the atoms follow a classic 'bottom left → top right' periodic trend.**

Typical Question: Arrange the following atoms in order of increasing atomic radii: Na, Be, Mg.



| | |
|---|---|
| | Be |
| Na | Mg |

**Questions of this type (as well as for other periodic trends) often select three elements from the periodic table that have a 'triangular' relationship. Understanding the classic 'bottom left → top right' periodic trend allows for the answer to be determined.**

Answer:

## 1st Ionization Energy

Discussion: What is *ionization*? What then is *1st ionization energy*?

**1st Ionization Energy: Energy *required* to remove the first electron from a gaseous atom or ion.**

Example: Sodium

$$Na\ (g) \rightarrow Na^{+}\ (g) + e^{-}\ ;\ I_1 = 496\ kJ/mol$$

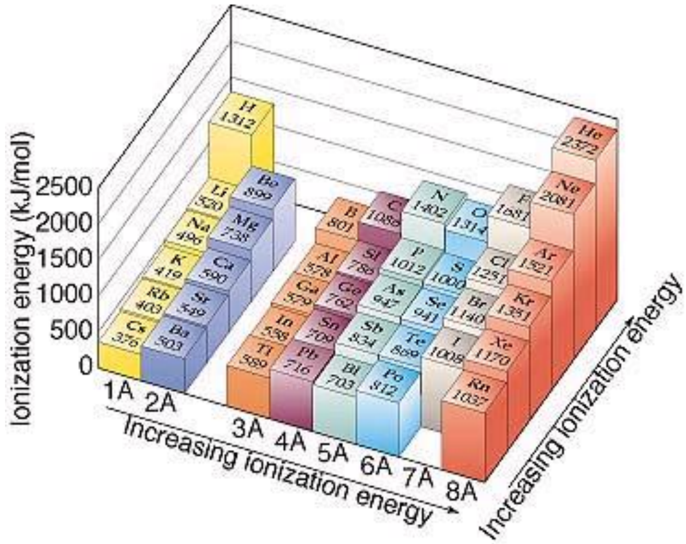
Task: Draw electron dot diagrams illustrating this process

Discussion: How do trends in 1st ionization energy of atoms ‘across a row’ and ‘down a column’ in the periodic table vary? Use the following figurse as a guide. Why do you think this is so?

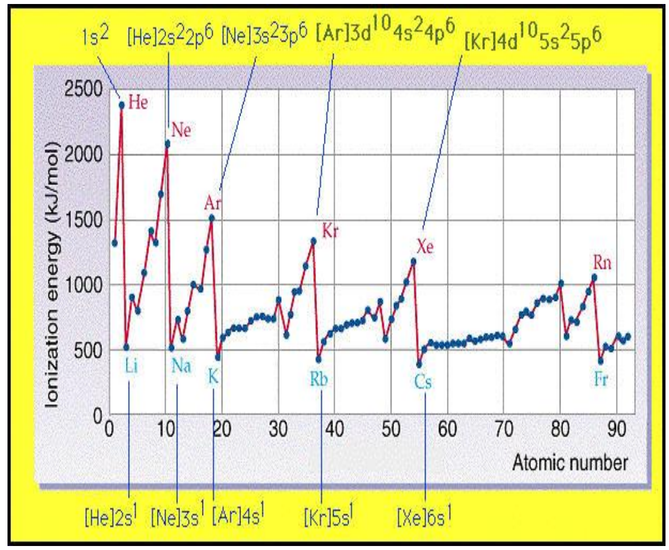
1. ‘Across a Row’

2. ‘Down a Column’

## Trends in 1st Ionization Energy

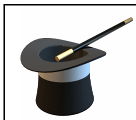



'Geographical' map of 1st ionization energy. Note the classic bottom left → top right trend




Line graph of $I_1$ vs atomic number.

Typical Question: Arrange the following atoms in order of increasing 1st ionization energy: Na, Cs, F, C.



**As with similar atomic radii, understanding the classic 'bottom left → top right' periodic trend allows for the answer to be determined.**

Answer:

# Intermolecular Forces

| Reading: Ch 14 sections 3 -6 | Homework: 14.3 questions 20, 22*, 24,26 |
|---|---|

* = 'important' homework question

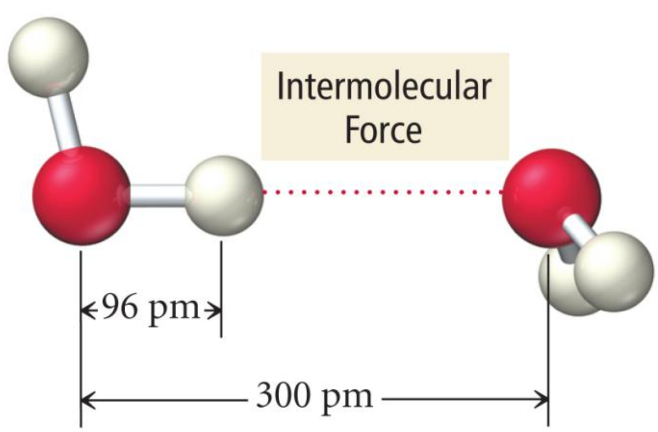
Background

Discussion: What is the difference between an ***inter****molecular* force and an ***intra***molecular force? Hint: Think about the difference between flying to Cleveland and Flying to Europe

*Intra*molecular Force:

*Inter*molecular Force:

Example: water

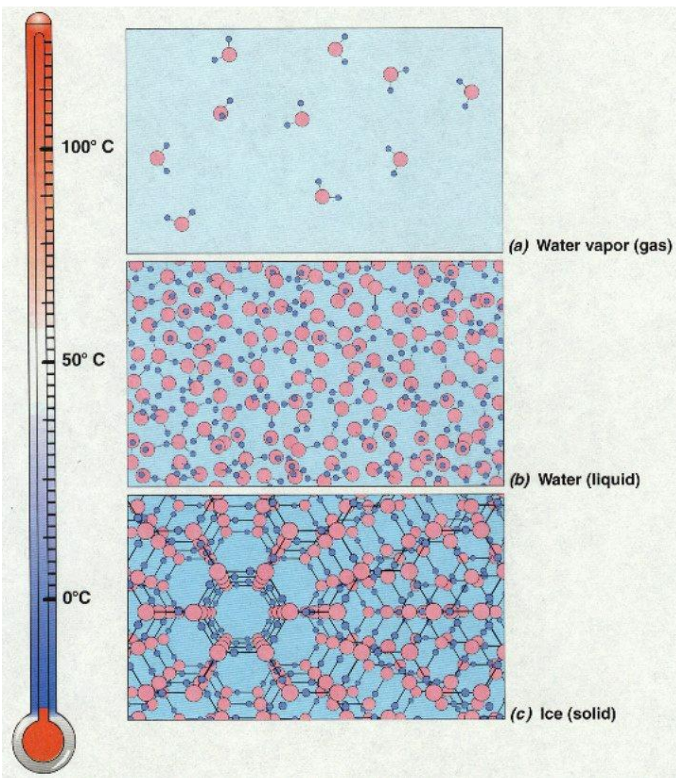


**Types of Intermolecular Forces (weak bonds *between* molecules)**

**Intermolecular forces are what hold *molecular* materials together in the liquid or solid state** (gases experience no intermolecular forces so are free to fill the container in which they are placed)

**Intermolecular bonds are broken when energy (heat) greater than the intermolecular bond strength is applied to the material**. This is why materials have specific melting and freezing points.

Recap: States of matter




Notes

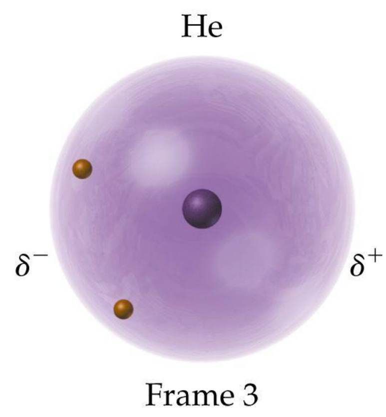
Overview: There are THREE types of intermolecular force (bond):

| Type of Force | Strength | Notes |
|---|---|---|
| London Dispersion Forces (induced dipole - dipole) | weak - strong | Common to ***all*** molecular materials |
| Dipole - Dipole | strong | Only for polar molecules |
| Hydrogen Bonding | very strong | Only for specific molecules |

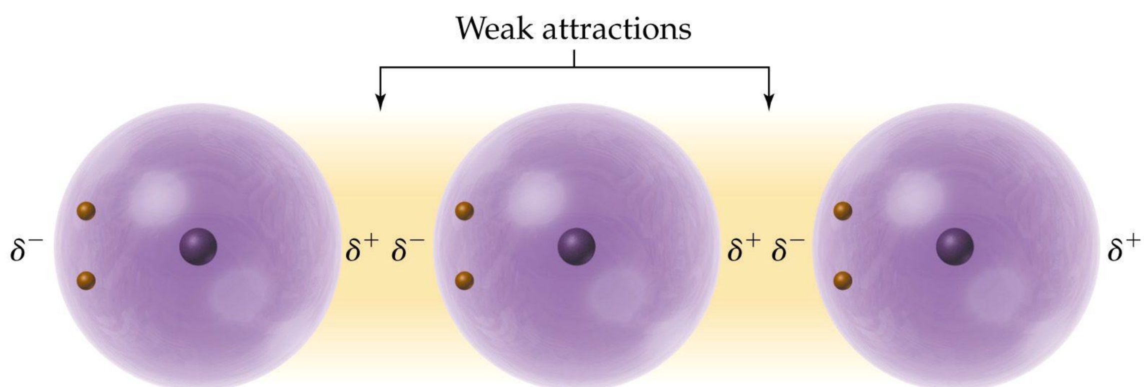
**London Dispersion Forces (induced dipole – dipole bonding)**

<u>Theory</u>:

1. Short lived *time dependant dipoles* are being created in atoms (and molecules) continually as electrons move around their respective orbital(s). Recall that a dipole is a special separation of charge. Since all atoms and molecules contain electrons, they all do this.




2. At close to the condensation point (gas - liquid), the atoms or molecules are moving slowly enough for an *induced dipole* to form between adjacent atoms or molecules. This spreads throughout the material, turning it to a liquid (or solid).



<u>Analogy</u>: Induced Dipole interactions are much like the 'wave' - seen at various sporting events when the crowd becomes 'bored' (like at Sox games).

CLASS DEMO: 'Helium in the house'

<u>Likely Exception</u>: British soccer – extreme boredom

"Com'on lads, let's see how they like the taste of this pointy metal fence"

<u>The strength of London Dispersion Forces</u>

<u>Discussion</u>: What basic property of an atom or molecule results in the formation of induced dipole – dipole bonding (London forces)? How then can the degree dipole – dipole bonding be increased? What *macroscopic* affect would this have?

**The strength of an induced dipole – dipole bond is proportional to the number of electrons an atom or molecule has.** Since atomic mass scales with the number of electrons:

**Strength of London of Forces ∝ Molecular mass ∝ boiling point***

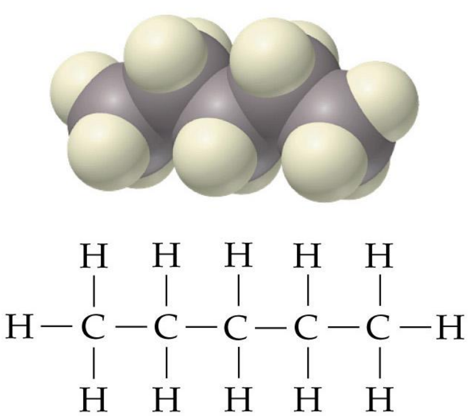
*for atoms and molecules that only have induced dipole-dipole intermolecular forces

Boiling Points, # electrons and Molar masses ($\mathcal{M}$) for the Nobel gases

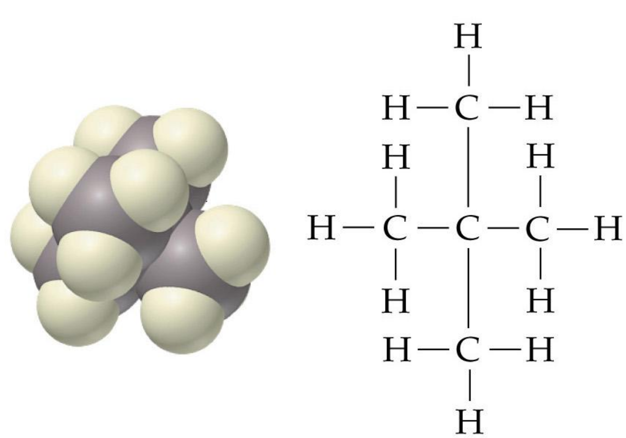
| Nobel Gas | # electrons | $\mathcal{M}$ (g/mole) | Bpt. (K) |
|---|---|---|---|
| He | 2 | 4.0 | 4.6 |
| Ne | 10 | 20.2 | 27.3 |
| Ar | 18 | 39.9 | 87.5 |
| Kr | 36 | 83.8 | 120.9 |

Molecular shape considerations

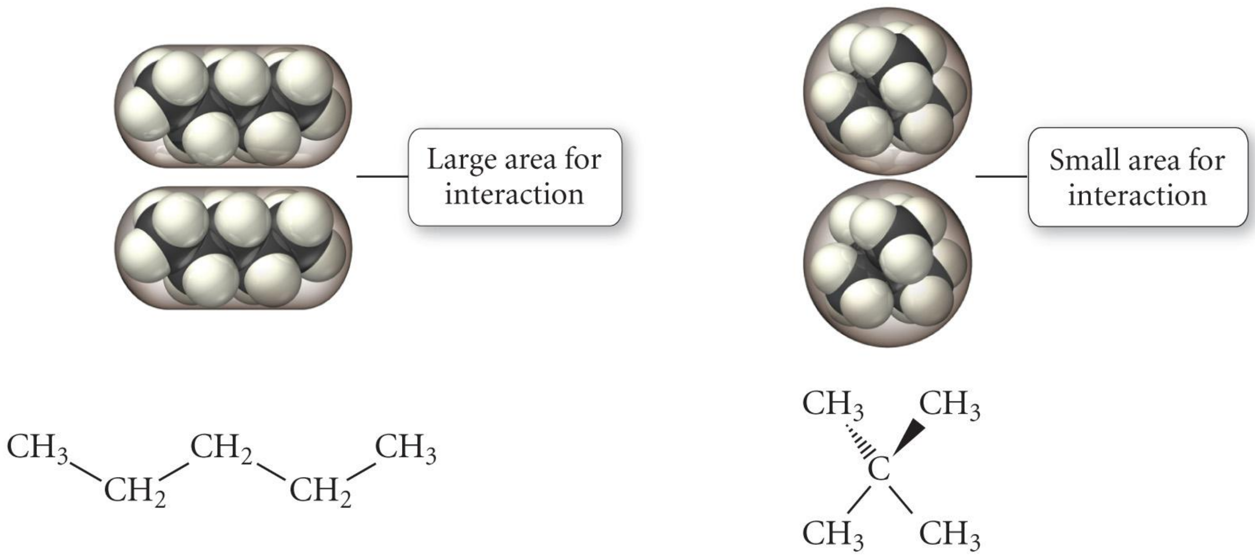
Discussion: Pentane (a) and isopentane (b) have identical molecular weights and molecular formulas. However, their shapes and boiling points are different. Explain.



**(a)** Pentane (bp = 309.4 K)



**(b)** 2,2-Dimethylpropane (bp = 282.7 K)




(a) *n*-Pentane

(b) Neopentane

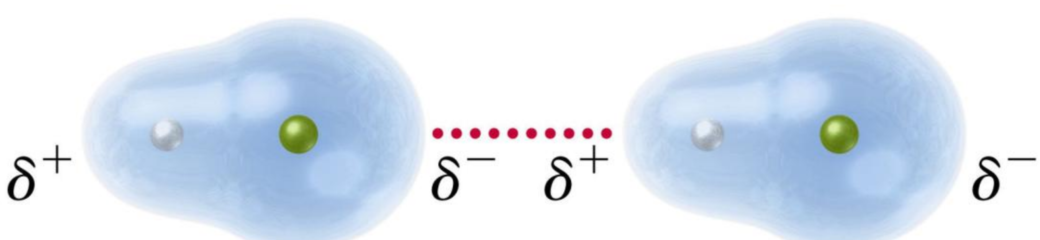
Dipole-Dipole and Dipole – Ion interaction

**A number of molecules have *permanent* dipoles, so experience stronger dipole–dipole interactions *in addition* to London dispersion forces.**

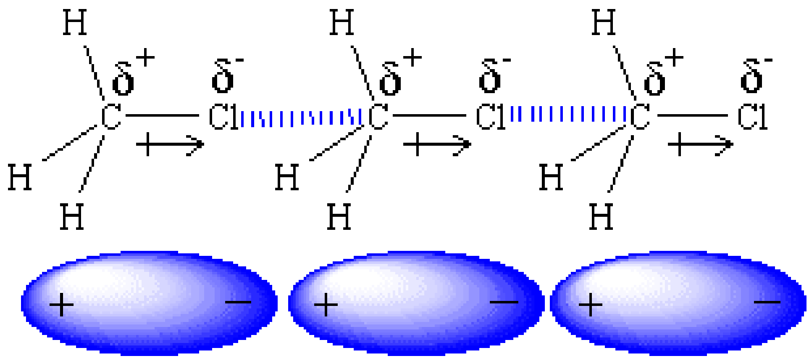
Recall: Polar molecules have a net dipole (separation of charge). HCl is a good example of a polar molecule.

The $\delta^+$ and $\delta^-$ ‘ends’ of polar molecules are attracted to one another – this is a dipole- dipole intermolecular force.

Example: HCl



Any molecule with a permanent dipole will undergo dipole-dipole intermolecular bonding. Example, $CH_3Cl$ (polar C-Cl bond)



The strength of a dipole-dipole intermolecular interaction is related to the strength of a molecule's permanent dipole (dipole moment).

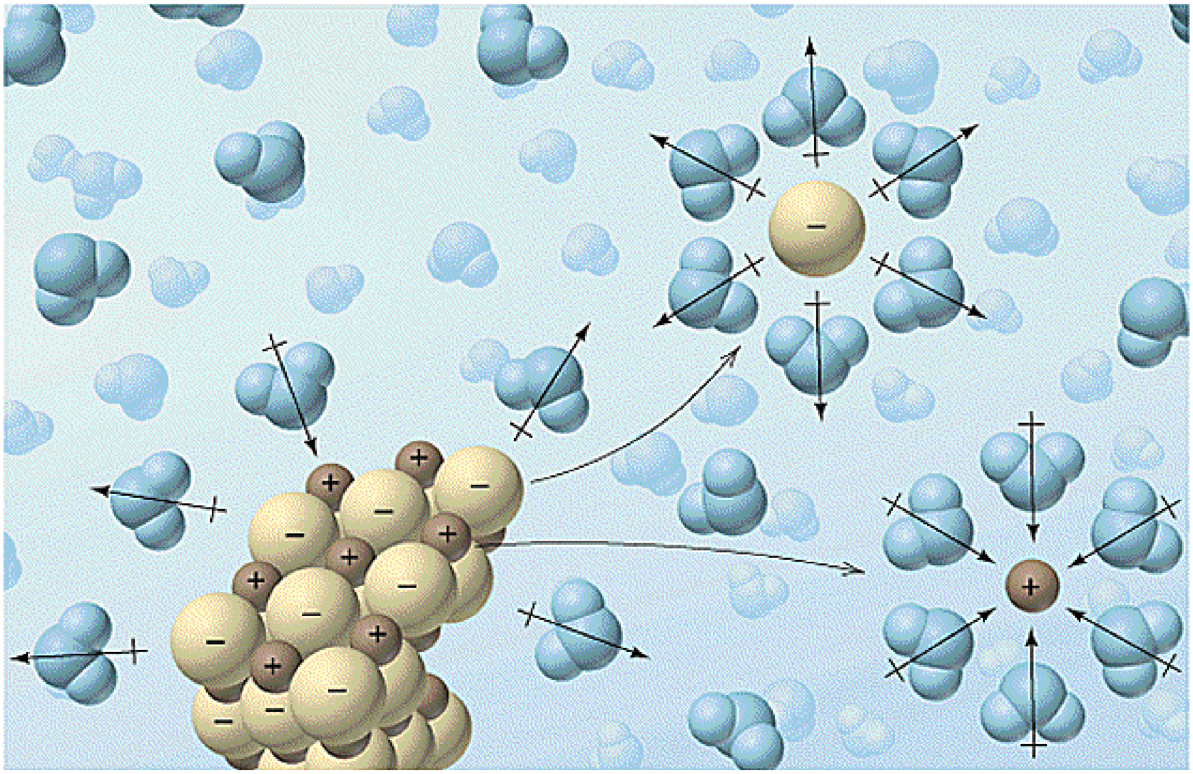
**Strength of dipole-dipole force $\propto$ Dipole moment $\propto$ boiling point**

Boiling Points, Dipole moments and Molar masses ($\mathcal{M}$) of some molecules

| Compound | Formula | $\mathcal{M}$ (g/mole) | Dipole moment ($\mu$) | Bpt. (K) |
|---|---|---|---|---|
| Propane | $CH_3CH_2CH_3$ | 44 | 0.1 | 231 |
| Ethanal | $CH_3CHO$ | 44 | 2.7 | 294 |
| Acetonitile | $CH_3CN$ | 41 | 3.9 | 355 |

Discussion: Table salt (NaCl) is very soluble in water – what type of intermolecular interaction is responsible for this fact?

Dipole – Ion interactions: NaCl (aq)



**Hydrogen Bonding**

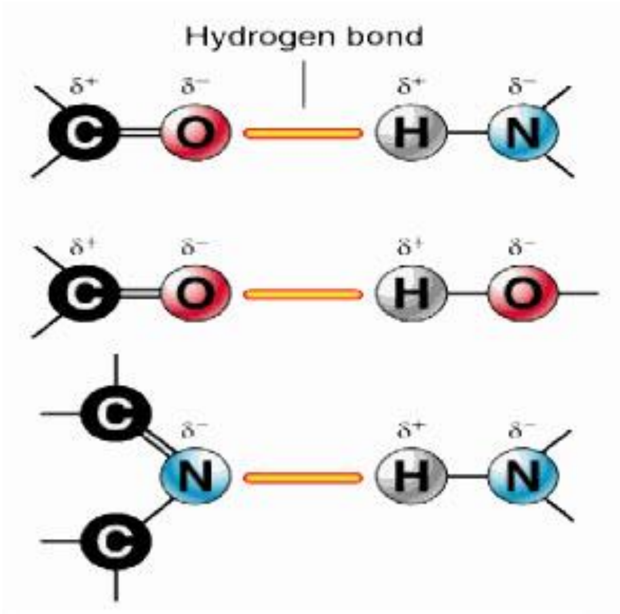
**Hydrogen bonding is a 'special' form of strong dipole-dipole interaction.**

**Hydrogen bonds are the strongest form of intermolecular force. A hydrogen bond is ~10% the strength as an intramolecular covalent bond.**

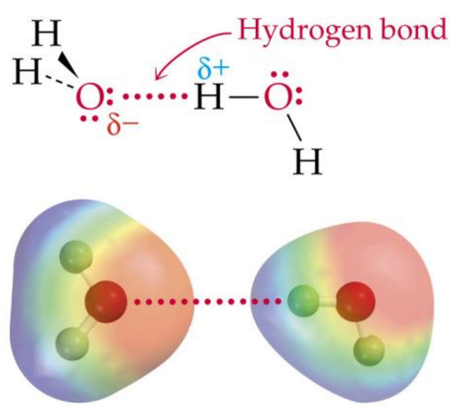
Requirements of a hydrogen bond: the **-X:**$^{\delta-}$ · · · · · $^{\delta+}$**H–**$^{\delta-}$**Y- coordinate**

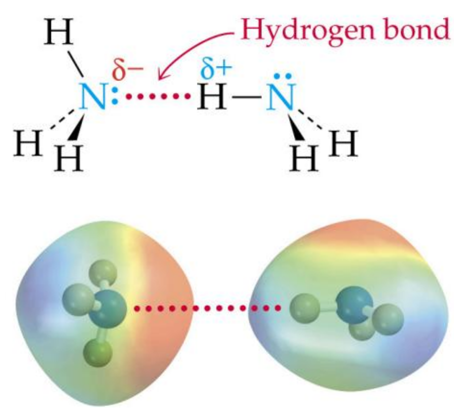
Diagram

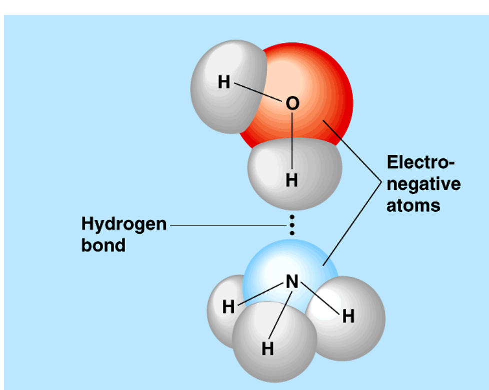
## Typical H-bond coordinates



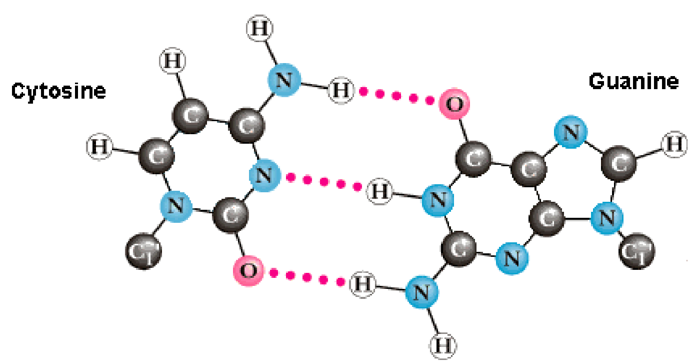

## Examples:



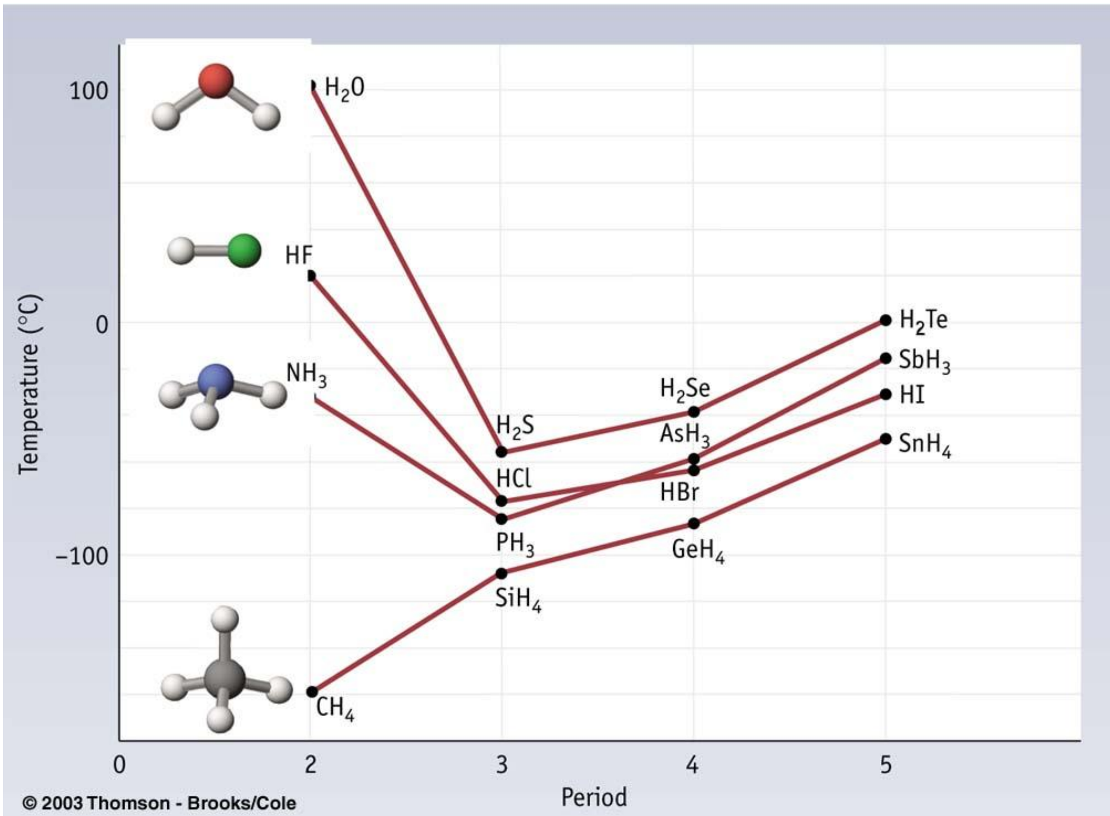





**Hydrogen bonding greatly increases the boiling points of H-bonded materials.** See figure.




<u>Summary</u>

- All materials have *induced* dipole –dipole / London Dispersion forces (they all have electrons)
- Additional permanent dipole – dipole or H- bonding interactions occur for a small subset of molecules with the necessary molecular features
- H-bonded materials have *much* greater boiling points that predicted using only London dispersion force trends (see above figure)

**H-bonding** >> **Dipole - Dipole** > **London dispersion**
*strongest* → *weakest*

# Loose Ends and Final Review

| | | | |
|---|---|---|---|
| Reading: | Ch 15 sections 1 - 8<br>(mostly lab review)<br>Ch 16 sections 1 – 5<br>(mostly lab review) | Homework: | 15.3 questions 16, 18, 20<br>15.4 questions 34*, 40<br>15.5 question 56<br>16.4 questions 38, 42<br>16.5 questions 56, 58 |

* = 'important' homework question

## Concentration and Dilution Considerations

Recall: The concentration of ANY solution is defined as:

**Concentration = Molarity (M) = number moles of *solute* per Liter of *solution***

i.e. Molarity = $\dfrac{\text{Moles Solute}}{\text{Liters Solution}}$   Units: mol/L or just M

Where:

**SOLUTION = SOLUTE + SOLVENT**

Dilutions: If the relationship between concentration of a solution, volume of a solution and moles of solute within the solution is rearranged we arrive at:

Moles = Concentration x Volume *or*

Moles = CV


Thought Experiment: After the final, you and a classmate (both over 21, of course!) head out to a bar and order a celebratory whisky and a whisky and soda, respectively. Think about the following questions regarding your beverages:

1. Which drink has the largest volume? Why?

2. Which drink is 'stronger' (most concentrated) in alcohol?

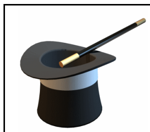
3. Which drink contains the most alcohol?

**Since both drinks contain one shot of whisky they contain the same # moles of alcohol. Since the whisky and soda has a larger volume (↑), it has a lower concentration (↓) of alcohol – it has been diluted. Mathematically we have:**

$$\textbf{Moles alcohol} = C_{whisky}V_{whisky} = C_{whisk\ \&soda\ (\downarrow)}V_{whisky\ \&soda\ (\uparrow)}$$

***or***

$$\textbf{Moles solute} = C_{before}V_{before} = C_{after}V_{after}$$



**When ever a solution is diluted, the volume of the resulting solution is greater, while its respective concentration is lower. The moles of solute remain constant**. i.e. $C_{before}V_{before} = C_{after}V_{after}$

Example: What is the concentration of the final solution when 250 mL of D.I. water is added to 125 mL of 0.50 M NaCl (aq) solution?

$C_{before}$ =

$C_{after}$ =

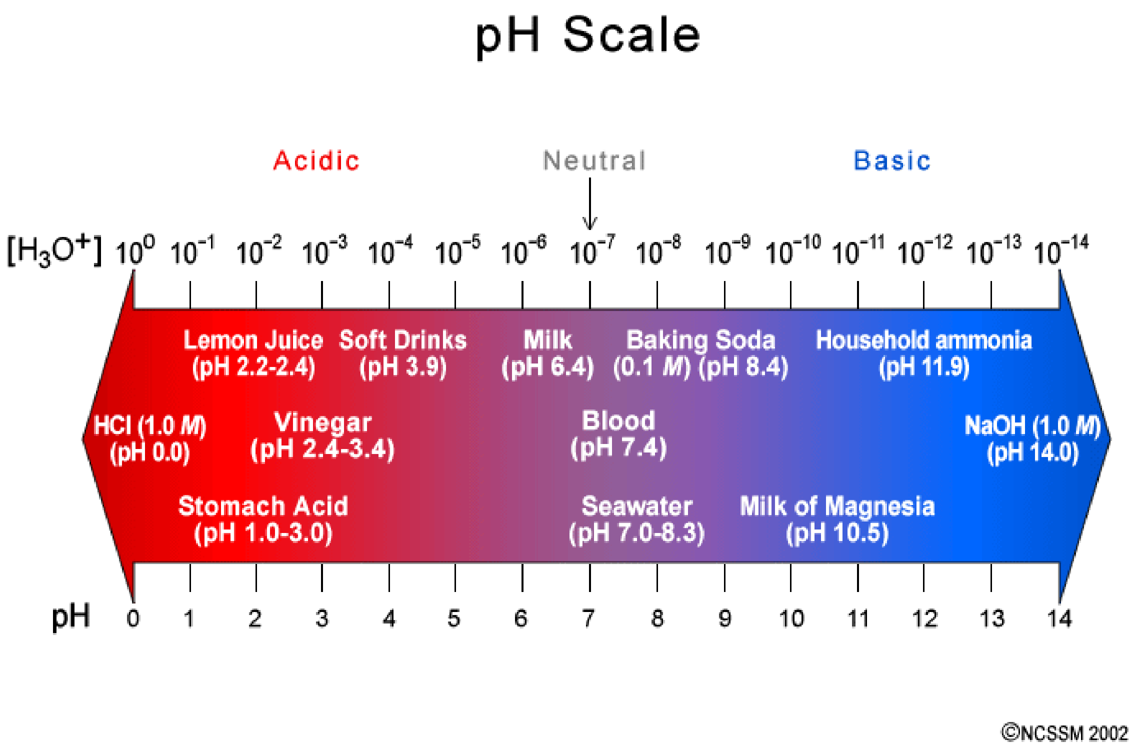
$V_{before}$ =

$V_{after}$ =

The pH Scale

Recall: pH is a measure of the level of acidity ($H^+$(aq) concentration) in a solution.

pH ranges: **1 – 6 (acidic), 7 (neutral), 8 – 14 (basic)**




**Examine the above figure. What is the simple, yet key, relationship between pH and $H_3O^+$ ($H^+$) ion concentration?**

Observation:

‘EZ’Examples (as found on the final)

A solution has a pH of 8. What is $[H^+]$ in the solution?

A solution of HCl has an $[H^+]$ of $1 \times 10^{-2}$ M? What is the solution’s pH?

**The mathematical relationship used convert between ‘powers’ and ‘regular’ numbers are the $\boxed{\log_{10}}$ and $\boxed{10^x}$ functions on your calculator, eg:**

$$\log 1 \times 10^3 = 3, \quad \textit{or} \quad 10^3 = 1 \times 10^3$$

**For the relationship between pH and $[H^+]$ we have a negative powers of 10, eg:**

**$[H^+] = 1 \times 10^{-3}$ when pH = 3, so the relationship between the two features a (-) sign:**

$$\boxed{pH = -\log [H^+] \quad \text{or} \quad [H^+] = 10^{-pH}}$$

‘Harder’ Examples (as found in the HWK)

Problem: You can’t figure out harder examples (see below) like an ‘EZ’ example because there is number other than ‘1’ in front of the ‘x10’ part. In such cases the formula must be used…

What is the pH of a solution that has a **$[H^+]$**value of $3.5 \times 10^{-3}$ M

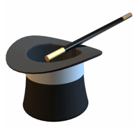
Key strokes (simple calculator): $\boxed{3.5}$ $\boxed{EE}$ $\boxed{+/-}$ $\boxed{3}$ then $\boxed{\log_{10}}$ then $\boxed{+/-}$

**Other Assorted 'Loose Ends'**

More ions

We committed a number of ion names and formulas to memory – the anions possess either *–ide* (mostly atomic anions, such as chlor*ide*, $Cl^-$) or *–ate* (molecular anions, such as $SO_4^{2-}$, sulf*ate*) suffixes. There are also many 'in between' molecular anions containing fewer, or occasionally more, oxygen atoms than the *-ate* ions. For example (from p 142):

| Ion formula | Name or ion |
|---|---|
| $Cl^-$ | chlor*ide* |
| $ClO^-$ | *Hypo*chlor*ite* |
| $ClO_2^-$ | Chlor*ite* |
| $ClO_3^-$ | Chlor*ate* |
| $ClO_4^-$ | *Per*chlor*ate* |



**The above table is worth memorizing, as there is likely to be one or two questions on the final regarding the 'in between' molecular anions of oxygen and chlorine.**

Example: Lithium chlorite has the formula:

a. $LiClO$
b. $LiClO_3$
c. $LiClO_2$
d. $LiClO_4$
e. $LiCl$

Solubility

A solubility chart will NOT be provided for final, although you will have access to a periodic table. This is not a problem, however, as there are only two basic facts to remember:

**Chlorides are mostly soluble - AgCl(s) is an important exception**

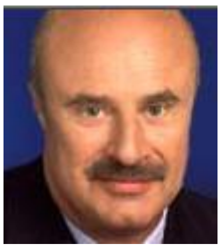
**Sulfates are mostly soluble – $BaSO_4$ (s) is an important exception**

**Use the above information to answer solubility questions on the final**

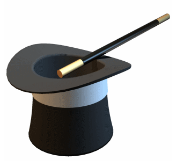
Percent Composition

We looked at this topic at the beginning of the empirical formulas work, but did not study it in isolation. There is likely to be a dedicated % composition question on your final, however, so some review of this work is worthwhile.

Try and work through this question in groups or individually. Pay particular attention to the math you use to work out the answer:



If Dr. Phil weighs 250 pounds and his head alone weighs 25 pounds, then what % by mass (% composition or mass percent) is Dr. Phil's head of his entire body?



In chemistry we do a very similar thing, but for molecules and formula units. This is called finding the % composition or mass percent

Example: What is the correct mass percent for each type of atom in $Al_2O_3$?

a. 47% Al 53% O
b. 53% Al 47% O
c. 26% Al 74% O
d. 84% Al 16% O
e. none of the above

**Final Exam Review**

Information

Your Final exam is a *comprehensive*, 70 question multiple choice (a – e) test. Questions are graded as either correct or incorrect. No points are subtracted for wrong guesses. There are two versions of the test, so your neighbors will have a different test.

I normalize your final exam score out of 70 to a score out of 200. This score out of 200 is included in your final course total.

Tips

The questions you will encounter are not, typically, 'super hard'. During the course I have concentrated on more challenging type questions that require you to hone your problem solving skills.

Due to the number of questions set and the time allowed, most of the multiple choice questions you will meet on the final may be considered to be 'lite' versions of my midterm and quiz questions. The following tips will help you record a better score on your final:

1. The test is ***cumulative***, so review everything we have covered since the beginning for the course.

2. Review ***all the topics***, but concentrate on topics you have had *difficulty* with. Since the questions are not 'super hard', this will increase your number of correct answers. Do not fall in to the trap of studying what you are good at (you'll get those questions right regardless, most likely), so preferentially study what you are 'bad' at.

3. Try to answer the questions *in order* when using a scantron sheet. It is better to guess a wrong answer (and then come back to it) than risk systematically filling out ovals 'a line out'.

4. *Work out the answers on the scratch paper provided*, then check the possible answers provided. This will cut down on 'red herring' type errors (see below)

5. Watch out for obvious 'red herrings', as illustrated by the following example. MOST questions DO NOT have a red herring, but a reasonable fraction do:

Example: CO is the formula for:

a. copper
b. carbon monoxide
c. cobalt
d. Monocarbon monoxide
e. None of the above

## Sample Final Exam Questions

1. The correct formula for magnesium oxide is:

a. $MgO_2$
b. $Mg_2O_3$
c. $MgO$
d. $Mg_3O_2$
e. None of the above

2. A solution has $[H^+] = 1 \times 10^{-8}$ M, the pH of the solution is:

a. 4
b. 0
c. -8
d. 8
e. None of the above

3. Which of the following is a non-metal?

a. nitrogen
b. lithium
c. iron
d. calcium
e. None of the above

4. Which of the following compounds is not a salt:

a. $NaOH$
b. $NaCl$
c. $Al(ClO_4)_3$
d. $NaNO_3$
e. None of the above

5. What is the mass of 10.0 moles of He:

a. 4.00 g
b. 8.00 g
c. 40.0 g
d. $6.02 \times 10^{23}$ g
e. None of the above

6. A 24.0 g sample of carbon contains how many atoms:

a. $6.02 \times 10^{23}$
b. $1.20 \times 10^{24}$
c. $3.01 \times 10^{23}$
d. $2.04 \times 10^{24}$
e. None of the above

7. The electronic configuration for the Ca atom is:

a. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$
b. $1s^2 2s^2 2p^6 3s^2$
c. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
d. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$
e. None of the above

8. Two moles of any gas will occupy what volume at STP?

a. 22.4 L
b. 11.2 L
c. 4.48 L
d. 44.8 L
e. None of the above

9. An example of a physical change is:

a. The rusting of iron
b. The burning of wood
c. The melting of ice
d. All of the above
e. None of the above

10. The number 0.000125 expressed in Scientific notation is:

a. $1.25 \times 10^{4}$
b. 125
c. $1.25 \times 10^{-4}$
d. $12.5 \times 10^{-3}$
e. $12.5 \times 10^{3}$

Answers:

| | | | |
|---|---|---|---|
| 1. | c. | 6. | b. |
| 2. | d. | 7. | c. |
| 3. | a. | 8. | d. |
| 4. | a. | 9. | c. |
| 5. | c. | 10. | c. |

**Post-Final Wrap Up**

General chemistry final exams are graded immediately after they have been completed by the students. The final exam scores (out of 200), as well as overall course scores and letter grades, will be available from 10:00 am on Thursday of exam week. **Students can check their scores by sending Dr. Mills an e-mail request at any time before noon on Thursday of exam week**. In order to ensure confidentiality, students requesting such feedback must include the following code word(s) within their e-mail requests:

**So Close, Yet so Far?**

Unfortunately, it is sometimes the case that students find themselves just a few points below the C/D (55%) cut-off line after the completion of all course materials. In order for such students to achieve a passing 'C' grades, an optional 25 pt. extra credit assignment may be completed. **Students may *only* complete this assignment if they contact Dr. Mills, via e-mail with a grade request, no later than noon on Thursday of exam week. Such students' final scores must have fallen no more than 25 points below the C/D cut-off in order for them to be eligible to take the assignment.**

Dr. Mills will supply qualifying students with a copy of the extra credit assignment, as an e-mail attachment, via return e-mail. **The hard deadline for completing this assignment is 10:00 am on Friday of exam week – no exceptions.**

Name: ____________________

Instructor: Mills

# Chemistry 100: 1st Practice Midterm Examination

*Answer all five questions*. Each question is worth 30 points. Please ensure you have all *five* pages of questions, as well as a formula sheet *before* starting work. For numerical answers, include the correct number of **significant figures** and appropriate **S.I. unit(s)**. For full credit you must….

# SHOW ALL WORK

| Question | Score |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| Total | |

## *"The wire"*

A copper (Cu) wire has a mass of 4.00 pounds and a diameter of 5.00 mm. **Determine the wire's mass, and volume in the units specified below. Include any appropriate decimal prefixes in your final answers**.
Density copper = 8.95 $gcm^{-3}$

Mass of the wire in kg:

Volume of the wire in $cm^3$:

# *"Conversions"*

Complete the following conversions (include correct number of sig. figs.):

<u>95.5 pounds to kg</u>

<u>1032 cm to meters</u>

<u>12.5 miles to km</u>

<u>-156 $^{o}$C to Kelvin</u>

<u>1300 Cal to kJ</u>

*“Mixtures, Elements and Compounds”*

State whether the following are classified as elements, compounds or mixtures:

Diamond:

Carbon dioxide gas:

Air:

A cup of coffee:

Water:

Sand ($SiO_2$):

Oxygen gas:

Gasoline

Fresh Milk:

Gold:

Ice Cube

A jar containing $H_2$ and $O_2$ gasses:

## *"Sketch"*

Sketch a fully labeled diagram illustrating the appearance of a 100 mL cylinder after the following items have been added to it:

| Material | Density ($g/cm^3$) |
|---|---|
| 40 mL D.I. water | 1.000 |
| A medium sized silver ring | 10.50 |
| 40 mL liquid mercury | 13.6 |
| A small gold coin | 19.32 |
| 20 mL Olive oil | 0.756 |

## *"Symbols"*

Write complete atomic symbols for the isotopes described by:

1. A mass number of 14 and an atomic number of 6

2. A total of 30 neutrons and 25 protons in it's nucleus

3. A total of 47 electrons and a mass number of 109

4. The isotope of chlorine with a mass number of 37

5. The isotope of potassium with 20 neutrons

## *"Ionic"*

Write the formulas and names of nine ionic compounds that may be formed through combining the anions and cations ions listed immediately below.

$H^{+}$ $Cu^{2+}$ $Al^{3+}$ $Cl^{-}$ $SO_4^{2-}$ $PO_4^{3-}$

| Ionic Formula | Name of Ionic Compound |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

# Data sheet (periodic table also provided)

Density = mass/volume
Density copper (Cu) = 8.95 $gcm^{-3}$
1 cm = 10 mm
Volume cylinder = $\pi r^2 h$

1 kg = 2.205 lb
1 inch = 2.54 cm
1 ft = 12 inches (exactly)
$1dm^3 = 1L = 10^{-3}m^3$

$1\ cm^3 = 1\ mL = 1\ x10^{-6}\ m^3$
1 mile = 1.6039 km
1 gallon = 3.786 L
1 Cal = 4.184 kJ

<u>Common Decimal Prefixes</u>

| Prefix | Symbol | Exponential Notation |
|---|---|---|
| Giga | G | $10^9$ |
| Mega | M | $10^6$ |
| Kilo | k | $10^3$ |
| deci | d | $10^{-1}$ |
| centi | c | $10^{-2}$ |
| milli | m | $10^{-3}$ |
| micro | μ | $10^{-6}$ |
| nano | n | $10^{-9}$ |

Name: ______________________________

Instructor: Mills

# Chemistry 100: 2nd Practice Midterm Examination

*Answer all five questions*. Each question is worth 30 points. Please ensure you have all *five* pages of questions, as well as a formula sheet *before* starting work. For numerical answers, include the correct number of **significant figures** and appropriate **S.I. unit(s)**. For full credit you must….

# SHOW ALL WORK

| Question | Score |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| Total | |

# *"Ionic"*

Write the formulas and names of nine ionic compounds that may be formed through combining the anions and cations ions listed immediately below.

$H^{+}$ $Cu^{2+}$ $Al^{3+}$ $Cl^{-}$ $SO_4^{2-}$ $PO_4^{3-}$

| Ionic Formula | Name of Ionic Compound |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

State whether your compounds from part 2a are soluble or insoluble:

Soluble Compounds

Insoluble Compounds

# *"Balance"*

Write balanced chemical equations that describe the following processes. Remember to include state symbols in your equations:

a. The burning of liquid propane ($C_3H_8$ (l)) in air

b. The Neutralization of stomach acid (hydrochloric acid solution) with caustic soda (sodium hydroxide solution)

c. The reaction of solid diphosphorus pentoxide with water to form aqueous phosphoric acid

d. The decomposition of chalk ($CaCO_3$), when heated, to form solid calcium oxide and carbon dioxide gas

e. The reaction of metallic zinc with aqueous sulfuric acid to form aqueous zinc sulfate and hydrogen gas

*Extra Credit: State to which one of the five* general *classes of reaction each of the above processes belong.*

## *"Those Three Equations"*

Write *balanced, complete* and *net* ionic equations illustrating the reaction between solutions of barium nitrate and sodium sulfate.

List the names and formulas of five insoluble ionic compounds containing the phosphate anion.

## *"Moles"*

**Expect a question relating to converting grams, volume of a gas and number of particles to and from moles of material (see HWK and class notes for examples)**

# *"Slides and Ladders"*

For the following *unbalanced* chemical reaction, determine the quantities listed below (Hint: balance the reaction first):

$$Fe(s) \quad + \quad O_2(g) \quad \rightarrow \quad Fe_2O_3(s)$$

The mass of iron (III) oxide produced when 2.56 g of solid iron is burnt in excess oxygen gas:

The number of oxygen molecules consumed in part (a)

***Extra Credit*: *State to which one of the five* general *classes of reaction the above processes belongs.***

## *"Electron addresses"*

Draw *Lewis symbols* and *'Dot' structures* for the following:

| Atom or Ion | Lewis Symbol | Dot Structure |
|---|---|---|
| C | | |
| $O^{2-}$ | | |

## *"Air bag"*

Vehicle safety 'air' bags actually inflate with nitrogen gas during collisions. If a standard car's 'air' bag has a volume of 36.0 L and inflates to a pressure of 745 Torr at 15 $^{o}$C, then:

<u>How many moles of $N_2$ (g) are contained within the inflated 'air' bag described above</u>?

<u>If the car's air bag described above was instead inflated at – 20 $^{o}$C (i.e. on a Chicago winter's day), to what pressure would the 'air' bag inflate?</u>

<u>Extra credit</u>: Do you think the process described in (b) would be dangerous? Explain.

## Data sheet (periodic table also provided)

| | | |
|---|---|---|
| Density = mass/volume | 1 kg = 2.205 lb | 1 $cm^3$ = 1 mL = 1 x$10^{-6}$ $m^3$ |
| Density copper (Cu) = 8.95 $gcm^{-3}$ | 1 inch = 2.54 cm | 1 mile = 1.6039 km |
| 1 a.m.u. = 1.6606 x $10^{-24}$ g | 1 ft = 12 inches (exactly) | 1 gallon = 3.786 L |
| Volume cylinder = $\pi r^2 h$ | 1$dm^3$ = 1L = $10^{-3}$$m^3$ | PV = nRT |
| R = 0.0821 Latm/molK | 1 atm = 760 Torr | $P_1V_1/T_1 = P_2V_2/T_2$ |

Common Decimal Prefixes

| Prefix | Symbol | Exponential Notation |
|---|---|---|
| Giga | G | $10^9$ |
| Mega | M | $10^6$ |
| Kilo | k | $10^3$ |
| deci | d | $10^{-1}$ |
| centi | c | $10^{-2}$ |
| milli | m | $10^{-3}$ |
| micro | µ | $10^{-6}$ |
| nano | n | $10^{-9}$ |

Solubility rules:

| **Soluble Compounds** | | Exceptions |
|---|---|---|
| Compounds containing | $NO_3^-$ | None |
| | $Cl^-$ | $Ag^+$, $Hg^{2+}$,$Pb^{2+}$ |
| | $Br^-$ | $Ag^+$, $Hg^{2+}$,$Pb^{2+}$ |
| | $I^-$ | $Ag^+$, $Hg^{2+}$,$Pb^{2+}$ |
| | $SO_4^{2-}$ | $Ba^{2+}$, $Hg^{2+}$,$Pb^{2+}$ |

| **Insoluble Compounds** | | Exceptions |
|---|---|---|
| Compounds containing | $CO_3^{2-}$ | $NH_4^+$ & group IA cations |
| | $PO_4^{3-}$ | $NH_4^+$ & group IA cations |
| | $OH^-$ | group IA cations $Ca^{2+}$,$Sr^{2+}$, $Ba^{2+}$ & $NH_4^+$ |

# Notes

s-block

New Designation
Original Designation

Non-Metals

Atomic #
Symbol
Atomic Mass

| | s-block 1 IA | 2 IIA | 3 IIIB | 4 IVB | 5 VB | 6 VIB | 7 VIIB | 8 VIIIB | 9 VIIIB | 10 VIIIB | 11 IB | 12 IIB | 13 IIIA | 14 IVA | 15 VA | 16 VIA | 17 VIIA | s-block 18 VIIIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 H 1.0094 | | | | | | | | | | | | | | | | | 2 He 4.00260 |
| 2 | 3 Li 6.941 | 4 Be 9.0122 | | | | | | | | | | | 5 B 10.81 | 6 C 12.011 | 7 N 14.007 | 8 O 15.999 | 9 F 18.998 | 10 Ne 20.179 |
| 3 | 11 Na 22.990 | 12 Mg 24.305 | | | | | | | | | | | 13 Al 26.982 | 14 Si 28.086 | 15 P 30.974 | 16 S 32.06 | 17 Cl 35.453 | 18 Ar 39.948 |
| 4 | 19 K 39.098 | 20 Ca 40.08 | 21 Sc 44.956 | 22 Ti 47.88 | 23 V 50.942 | 24 Cr 51.996 | 25 Mn 54.938 | 26 Fe 55.847 | 27 Co 58.933 | 28 Ni 58.69 | 29 Cu 63.546 | 30 Zn 65.39 | 31 Ga 69.72 | 32 Ge 72.59 | 33 As 74.922 | 34 Se 78.96 | 35 Br 79.904 | 36 Kr 83.80 |
| 5 | 37 Rb 85.468 | 38 Sr 87.62 | 39 Y 88.906 | 40 Zr 91.224 | 41 Nb 92.906 | 42 Mo 95.94 | 43 Tc (98) | 44 Ru 101.07 | 45 Rh 102.91 | 46 Pd 106.42 | 47 Ag 107.87 | 48 Cd 112.41 | 49 In 114.82 | 50 Sn 118.71 | 51 Sb 121.75 | 52 Te 127.60 | 53 I 126.91 | 54 Xe 131.29 |
| 6 | 55 Cs 132.91 | 56 Ba 137.33 | 57 to 71 | 72 Hf 178.49 | 73 Ta 180.95 | 74 W 183.85 | 75 Re 186.21 | 76 Os 190.2 | 77 Ir 192.22 | 78 Pt 195.08 | 79 Au 196.97 | 80 Hg 200.59 | 81 Tl 204.38 | 82 Pb 207.2 | 83 Bi 208.98 | 84 Po (209) | 85 At (210) | 86 Rn (222) |
| 7 | 87 Fr (223) | 88 Ra 226.03 | 89 to 103 | 104 Unq (261) | 105 Unp (262) | 106 Unh (263) | 107 Uns (262) | 108 Uno (265) | 109 Une (266) | 110 Uun (267) | | | | | | | | |

s-block — d-block — Transition Metals — p-block

Metals

(Mass Numbers in Parentheses are from the most stable of common isotopes.)

| Phases |
|---|
| Solid |
| Liquid |
| Gas |

***Rare Earth Elements***

| | d-block | f-block | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lanthanide Series** | 57 La 138.91 | 58 Ce 140.12 | 59 Pr 140.91 | 60 Nd 144.24 | 61 Pm (145) | 62 Sm 150.36 | 63 Eu 151.96 | 64 Gd 157.25 | 65 Tb 158.93 | 66 Dy 162.50 | 67 Ho 164.93 | 68 Er 167.26 | 69 Tm 168.93 | 70 Yb 173.04 | 71 Lu 174.97 |
| **Actinide Series** | 89 Ac 227.03 | 90 Th 232.04 | 91 Pa 231.04 | 92 U 238.03 | 93 Np 237.05 | 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 (260) |