CASPER Research Experience for Teachers

Lisa Tarman, William Penn Senior High School

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Overview of Summer

The RET Project for 2012 was a nice mix of "teacher work" that I am accustomed to, and "scientist work" where I learned a lot.

The educational component laid the groundwork for transitioning the elaborate annual Physics Circus undertaking into a web-based experience. We became familiar with the 2010 Physics Circus, aligned the science content to Texas and national Standards, and developed a 3 tiered curriculum. The 2010 circus had a mystery theme. We organized our work by the five "clues" to solve the mystery. My work covered the fourth clue. I developed a vocabulary list, tiered objectives, curriculum content, and a question bank for my clue.

Our home base was a table in the CASPER Lab, so even as we worked on curriculum we were part of a research environment. There were opportunities to observe multiple experiments and interact with the researchers. I assisted Dr. Angela Douglass as she investigated the vertical interactions of a chain of particles confined in a square glass box. I was involved with causing and breaking the high vacuum, jabbing a particle in the chain with a green laser and operating the side camera.

As a group with Jorge Carmona-Reyes' help, the four RET teachers conducted our own experiment on Cell 1 to see the effect of lasers on a single layer of gold coated particles. I gained a lot of insight into what a researcher experiences. I learned a lot as I extracted data from 1000 images, by tracking thousands of particle trajectories and using a spreadsheet to make sense of it.

In addition to our curriculum work and research there were other opportunities to interact with the professors and REU students. There were weekly update meetings where we learned the progress REU students were making. Wednesday lunch speakers covered a variety of Baylor research topics. Field trips to the observatory and the Space X rocket testing facility were very interesting and informative. The summer culminated with a lovely final banquet where each participant was recognized.

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STANDARDS

CONTENT STANDARD B:

Chapter 112. Texas Essential Knowledge and Skills for Science

Subchapter C. High School

(6) Science concepts. The student knows and understands the historical development of atomic theory. The student is expected to:

(E) express the arrangement of electrons in atoms through electron configurations and Lewis valence electron dot structures.

(7) Science concepts. The student knows how atoms form ionic, metallic, and covalent bonds. The student is expected to:

(B) write the chemical formulas of common polyatomic ions, ionic compounds containing main group or transition metals, covalent compounds, acids, and bases;

8) Science concepts. The student can quantify the changes that occur during chemical reactions. The student is expected to:

(D) use the law of conservation of mass to write and balance chemical equations;

OBJECTIVES

LEV 1 -

- Identify information provided on a periodic table (atomic number, symbol, atomic mass, name)
- Explain the difference between the use of subscripts and coefficients
- Identify 2 element compounds on a mass spectrometer graph & determine the formula
- State the law of conservation of mass
- Balance chemical equations

LEV 2 -

- Use a periodic table to determine valance charge
- Use STAAR reference material to determine valence charge of polyatomic ions
- Write formulas for compounds including polyatomic ions

  http://www.ausetute.com.au/namiform.html
- Identify complicated compounds on a mass spectrometer graph & determine the formula
- State the law of conservation of mass
- Balance chemical equations

LEV 3 -

- Write formulas for compounds including polyatomic ions
- Identify complicated compounds on a mass spectrometer graph & determine the formula
- Write a balanced equation for a synthesis, decomposition, single replacement, or double replacement reaction given a mass spectrometer graph of the reactants.

VOCABULARY:

Atomic number - the number of protons found in the nucleus of an atom

Mass number - the sum of the number of protons and neutrons of an atomic nucleus.

Atomic mass unit - one twelfth of the mass of an unbound atom of carbon-12. It is a unit of mass used to express atomic masses

Subscript – small lower number that shows the ratio of elements present in the compound

Coefficient - the numbers in front of the compounds or molecules in a chemical equation

Mass spectrometer - a scientific instrument used to measure the masses and relative abundances of a vaporized and ionized sample

Law of conservation of mass - the mass of an isolated system (closed to all matter and energy) will remain constant over time

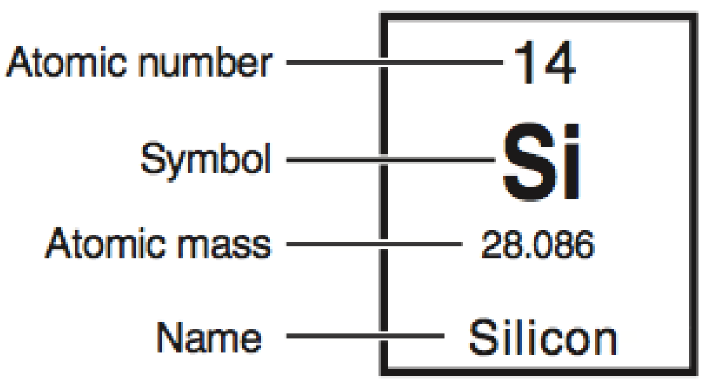
Polyatomic ion - a tightly bound group of atoms that behaves as a unit and has a positive or negative charge

CURRICULUM:

Level 1

Each chemical element in the universe has unique properties that distinguish it from all of the other chemical elements. Though each is unique, the elements can be still grouped by their commonalities in a useful and meaningful way. The periodic table groups the elements by properties.

Each element has its own box and these boxes make up groups and rows. There are eighteen groups (or families or columns) on the periodic table. Each one represents how many electrons are attached to the elements and correlate to how many valence electrons are present. Electrons are negatively charged subatomic particles that revolve around the nucleus of the element. Valence electrons are electrons that are on the very outside of the atom. There are seven periods (or horizontal rows) that describe electron shells.
Each box on the periodic table has certain informative parts about the element.



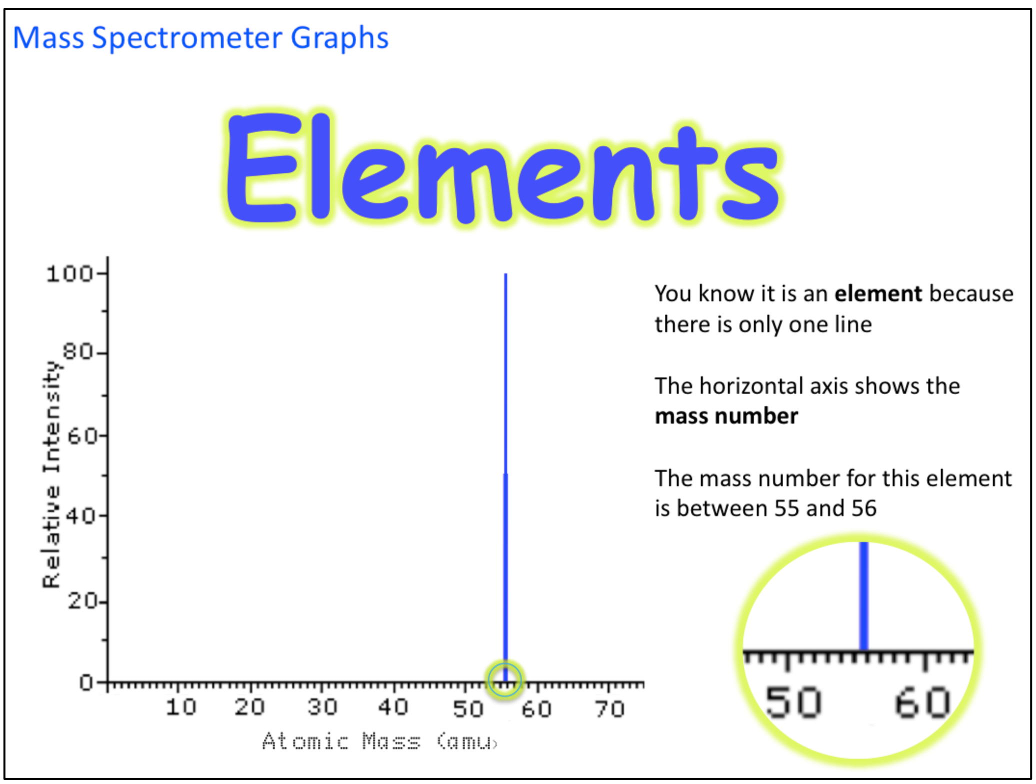
The "14" on the top is the atomic number, which deals with how many protons, or positive charges, are in the atom.
The "Si" is the symbol for Silicon. All the elements get a one or two letter symbol (there are a couple of exceptions with undeclared elements).
The number under the symbol is the atomic weight or atomic mass. 28.086 represents how many grams are in each mole (6.022×10^{23} entities) of hydrogen.

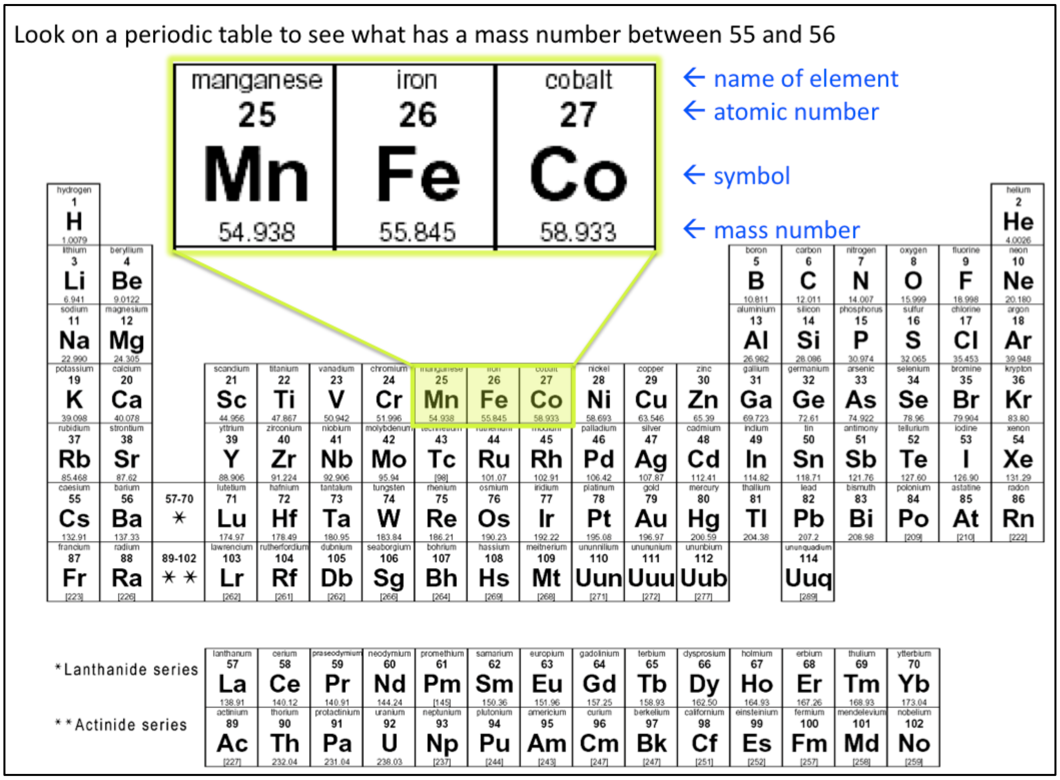
Compounds are pure substances made up of 2 or more elements. Each compound has a formula showing which elements are present in a molecule and how many of each. A water molecule, H_2O, has two atoms of hydrogen and 1 atom of oxygen. The small **subscript** numbers show the number of each atom. If there is no subscript, it is 1. A molecule of glucose has 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms, so it is written $C_6H_{12}O_6$. If there were 3 molecules of water, we would not change the subscipts, we would add a **coefficient** out in front like this $2H_2O$. Four molecules of glucose would be $4C_6H_{12}O_6$. Four molecules of glucose would have a total of 24 atoms of carbon, each molecule has 6 atoms of carbon and there are 4 molecules. 6x4 = 24

A **mass spectrometer** can be used to determine the chemical make up of an unknown compound.

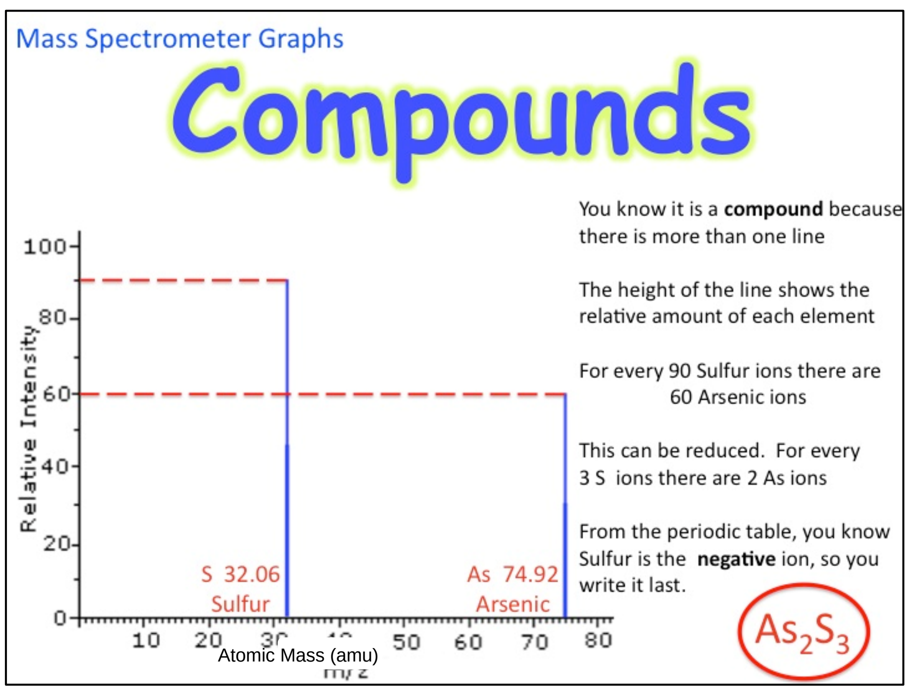
The graph from a mass spectrometer identifies the atomic mass and relative ratio of the sample.

To simplify, we will consider the graph of a pure element:





A mass spectrometer usually wouldn't be used for a pure sample of one element.



Usually whichever element is farther left of the periodic table is written first in the formula.

The **law of conservation of mass**, states that the mass of an isolated system (closed to all matter and energy) will remain constant over time. Even when there are chemical changes, mass must be conserved. In a chemical reaction, the number and types of atoms in the reactants, must equal the number and types of atoms in the products.

Consider this chemical equation: $FeS + HCl \rightarrow FeCl_2 + H_2S$

Iron(II)sulfide and hydrochloric acid have a double replacement reaction to produce Iron(II)chloride and hydrogen sulfide.

As written, this violates the law of conservation of mass. It starts with one chlorine atom, and ends with two. Changing the subscripts would change the compound. The equation must be "balanced" by adding coefficients, numbers in front of the molecule.

$$FeS + 2HCl \rightarrow FeCl_2 + H_2S$$

Having 2 molecules of HCl for every 1 molecule of FeS balances the equation. Each side of the equation has 1 Fe, 1 S, 2 H, and 2 Cl.

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Level 2

Positively charged ions are called ***cations***. Negatively charged ions are called ***anions***.

The cation is always written first when ions form compounds.

You can determine how ions combine if you know the ***valency***.

Valency or **valence number**, is a measure of the number of bonds formed by an atom of a given element. For many elements, you can determine the most common valence number by it's placement on the periodic table.

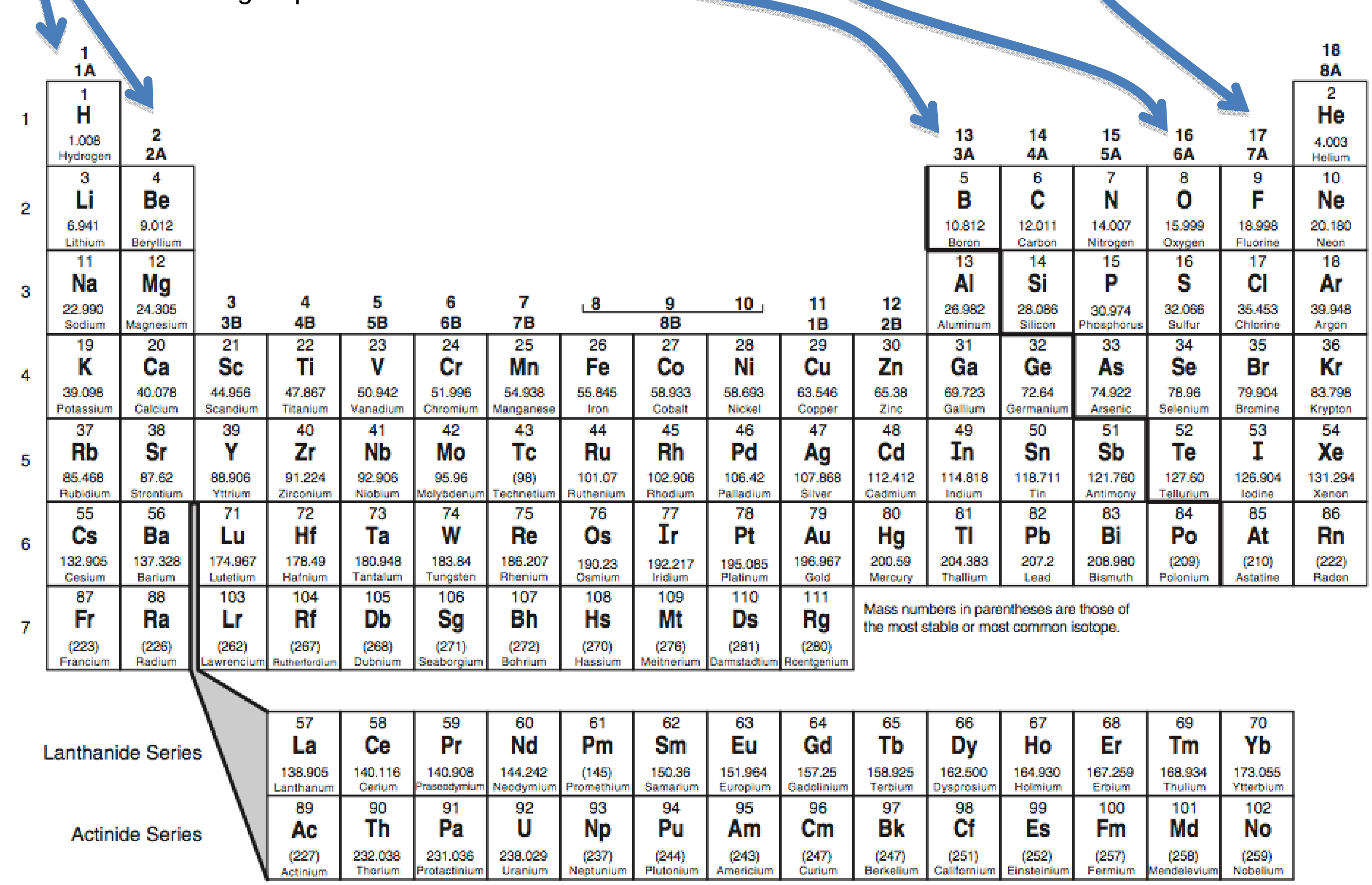
Elements in group 1A have valence number +1

Elements in group 2A have valence number +2

Elements in groups 3A have valence number +3

Elements in group 6A have valence number -2

Elements in group 7A have valence number -1



Some elements you just need to know or look up their valance number, like zinc is +2 and silver is +1. And for some metals that can have more than one charge (valency). the name of the metal is succeeded by the valency in capital Roman numerals in brackets.   Copper(I) has a charge of +1 and tin(IV) has a charge of +4.

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A ***polyatomic ion*** is a charged species (ion) composed of two or more atoms covalently bonded that can be considered as acting as a single unit. A list of common polyatomic ions and their valence numbers are in the STAAR Reference Material.

POLYATOMIC IONS	
Acetate	$C_2H_3O_2^-$, CH_3COO^-
Ammonium	NH_4^+
Carbonate	CO_3^{2-}
Chlorate	ClO_3^-
Chlorite	ClO_2^-
Chromate	CrO_4^{2-}
Cyanide	CN^-
Dichromate	$Cr_2O_7^{2-}$
Hydrogen carbonate	HCO_3^-
Hydroxide	OH^-
Hypochlorite	ClO^-
Nitrate	NO_3^-
Nitrite	NO_2^-
Perchlorate	ClO_4^-
Permanganate	MnO_4^-
Phosphate	PO_4^{3-}
Sulfate	SO_4^{2-}
Sulfite	SO_3^{2-}

The raised superscript shows the charge.

A lone sign is assumed to be 1.

Acetate has a charge of -1.

Carbonate has a charge of -2

When ions or polyatomic ions combine, they form a <u>neutral</u> molecule.
The ions combine in ratios such that the charges all cancel out.
If you want to combine Al^{+3} with Cl^{-1}, you would need **3** chlorines for each Aluminum so the charges cancel. +3 and -1 -1 -1 cancel out.
A subscript in the formula shows how many of each ion is present.

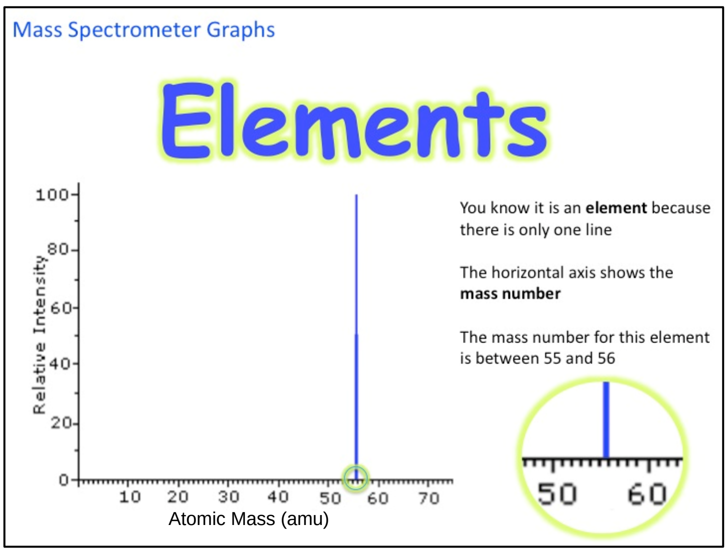
Remember that the cation is always written first in a compound.
Aluminum combining with chlorine would be written $AlCl_3$

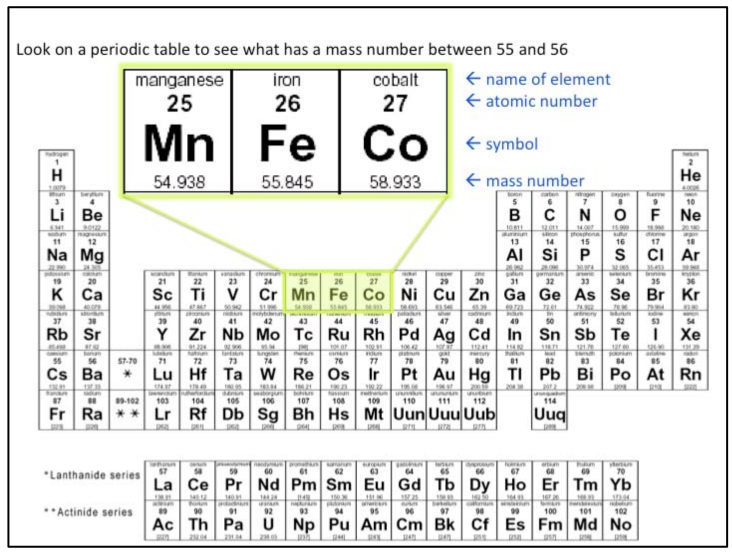
If you combine zinc (+2) with the polyatomic ion nitrate (-1), you would need two nitrates for each zinc. The formula would be $Zn(NO_3)_2$

Parenthesis are used whenever there is more than one polyatomic ion.

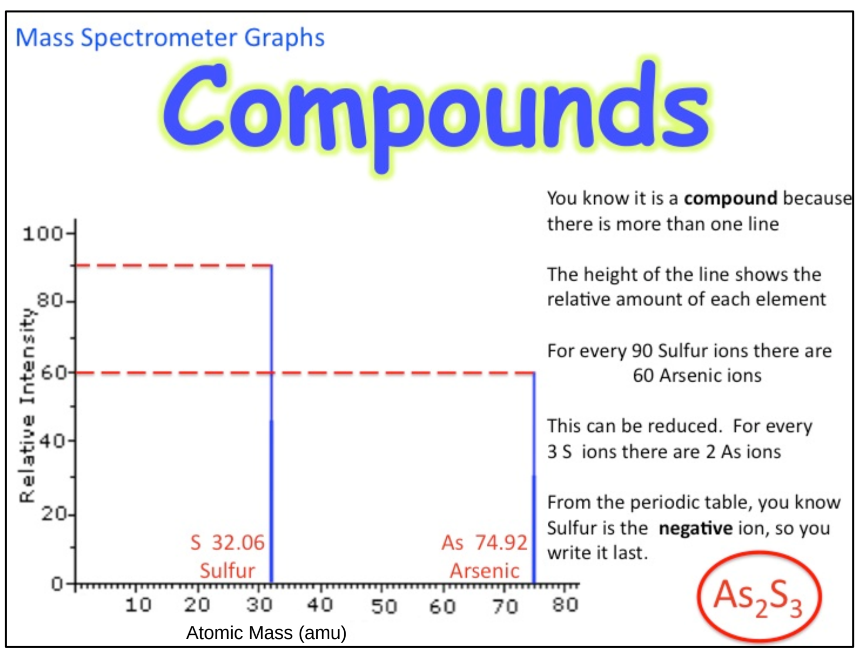
A **mass spectrometer** can be used to determine the chemical make up of an unknown compound.

The graph from a mass spectrometer identifies the atomic mass and relative ratio of the sample.





A mass spectrometer usually wouldn't be used for a pure sample of one element.



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The **law of conservation of mass**, states that the mass of an isolated system (closed to all matter and energy) will remain constant over time. Even when there are chemical changes, mass must be conserved. In a chemical reaction, the number and types of atoms in the reactants, must equal the number and types of atoms in the products.

Consider this chemical equation: $FeS + HCl \rightarrow FeCl_2 + H_2S$

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Having 2 molecules of HCl for every 1 molecule of FeS balances the equation. Each side of the equation has 1 Fe, 1 S, 2 H, and 2 Cl.

Be careful when there are polyatomic ions in parenthesis.

Consider this chemical equation: $Hg(OH)_2 + H_3PO_4 \rightarrow Hg_3(PO_4)_2 + H_2O$

There are 5 hydrogen ions on the left side – 2 from the hydroxide and 3 in the second compound.

On the right side, only water has hydrogen – so it comes in sets of two. An *odd* number of hydrogens on the left will never balance! So a good start is to put a 2 in front of the H_3PO_4. To make the mercury (Hg) balance, put a 3 in front of the mercury hydroxide. Tally up the number of each ion on the left, and determine what coefficients are needed on the right.

$$3Hg(OH)_2 + 2H_3PO_4 \rightarrow Hg_3(PO_4)_2 + 6H_2O$$

3 Hg		3	3 Hg		3
6 O	8 O	14	8 O	6 O	14
6 H	6 H	12		12 H	12
	2 P	2	2 P		2

Level 3 (overlaps some parts of Lev 2)

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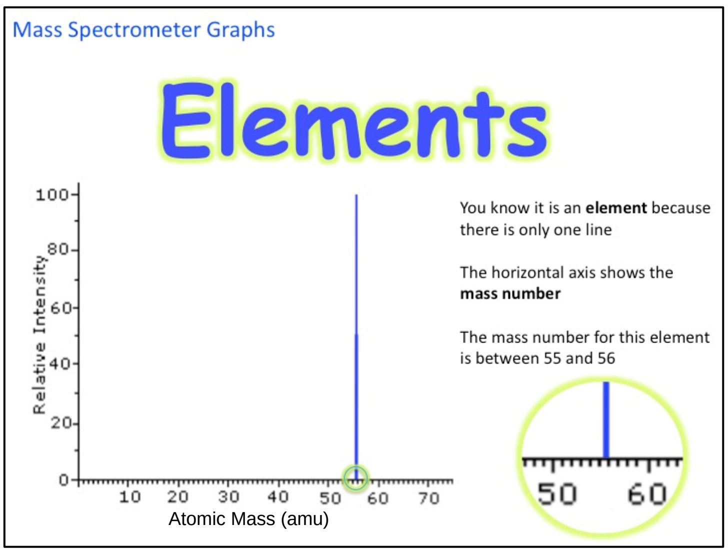

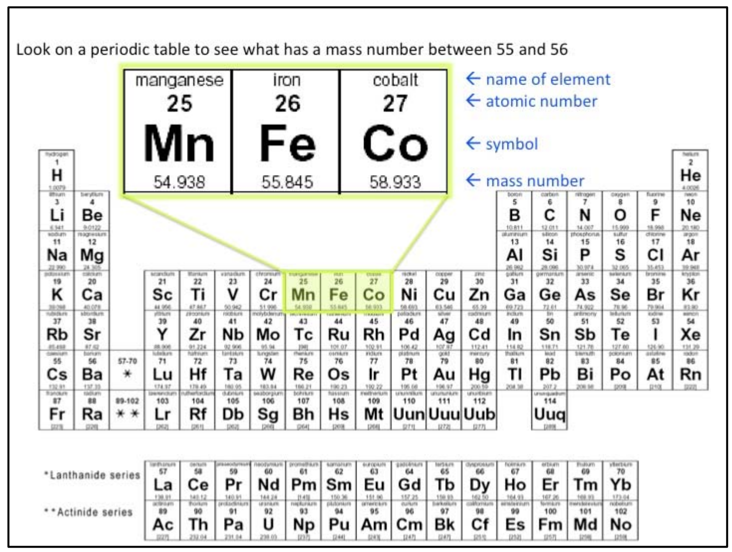

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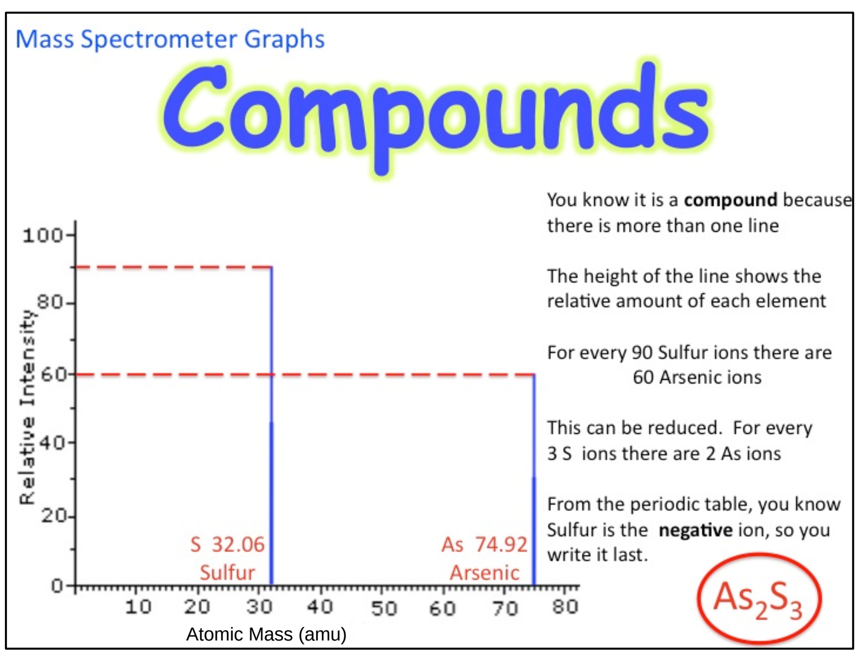

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6 H	6 H	12		12 H	12
	2 P	2	2 P		2

The following is adapted from : http://misterguch.brinkster.net/6typesofchemicalrxn.html

All chemical reactions can be placed into one of six categories.

1) **Combustion**: A combustion reaction is when oxygen combines with another compound to form water and carbon dioxide. These reactions are exothermic, meaning they produce heat. An example of this kind of reaction is the burning of napthalene:

$$C_{10}H_8 + 12\ O_2 \rightarrow 10\ CO_2 + 4\ H_2O$$

2) **Synthesis**: A synthesis reaction is when two or more simple compounds combine to form a more complicated one. These reactions come in the general form of:

$$A + B \rightarrow AB$$

One example of a synthesis reaction is the combination of iron and sulfur to form iron (II) sulfide:

$$8\ Fe + S_8 \rightarrow 8\ FeS$$

3) **Decomposition**: A decomposition reaction is the opposite of a synthesis reaction - a complex molecule breaks down to make simpler ones. These reactions come in the general form:

$$AB \rightarrow A + B$$

One example of a decomposition reaction is the electrolysis of water to make oxygen and hydrogen gas:

$$2\ H_2O \rightarrow 2\ H_2 + O_2$$

4) **Single displacement**: This is when one element trades places with another element in a compound. These reactions come in the general form of:

$$A + BC \rightarrow AC + B$$

One example of a single displacement reaction is when magnesium replaces hydrogen in water to make magnesium hydroxide and hydrogen gas:

$$Mg + 2\ H_2O \rightarrow Mg(OH)_2 + H_2$$

5) **Double displacement**: This is when the anions and cations of two different molecules switch places, forming two entirely different compounds. These reactions are in the general form:

$$\mathbf{AB + CD \rightarrow AD + CB}$$

One example of a double displacement reaction is the reaction of lead (II) nitrate with potassium iodide to form lead (II) iodide and potassium nitrate:

$$Pb(NO_3)_2 + 2\ KI \rightarrow PbI_2 + 2\ KNO_3$$

6) **Acid-base**: This is a special kind of double displacement reaction that takes place when an acid and base react with each other. The H^+ ion in the acid reacts with the OH^- ion in the base, causing the formation of water. Generally, the product of this reaction is some ionic salt and water:

$$HA + BOH \rightarrow H_2O + BA$$

One example of an acid-base reaction is the reaction of hydrobromic acid (HBr) with sodium hydroxide:

$$HBr + NaOH \rightarrow NaBr + H_2O$$

Question Bank – Clue 4

Level 1

How many sodium ions are in $2Na_2O$?

Answer: 4

How many lead ions are in $3Pb_3N_2$?

Answer: 9

How many nitrogen ions are in $3Pb_3N_2$?

Answer: 6

How many copper ions are in Cu_3P_2?

Answer: 3

How many iron ions are in $2FeBr_2$?

Answer: 2

How many bromine ions are in $2FeBr_2$?

Answer: 4

How many carbon ions are in $2C_{12}H_{22}O_{11}$?

Answer: 24

How many oxygen ions are in $2C_{12}H_{22}O_{11}$?

Answer: 22

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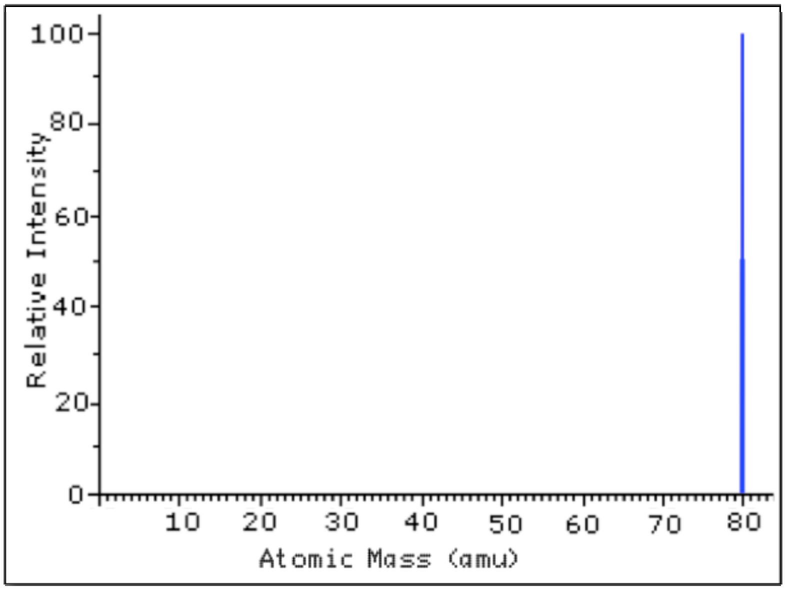
What is the function of a mass spectrometer?

A. to measure the mass of an unknown substance
B. to measure the spectrum of radiation reflected by an unknown substance
C. to determine the elements that make up an unknown substance

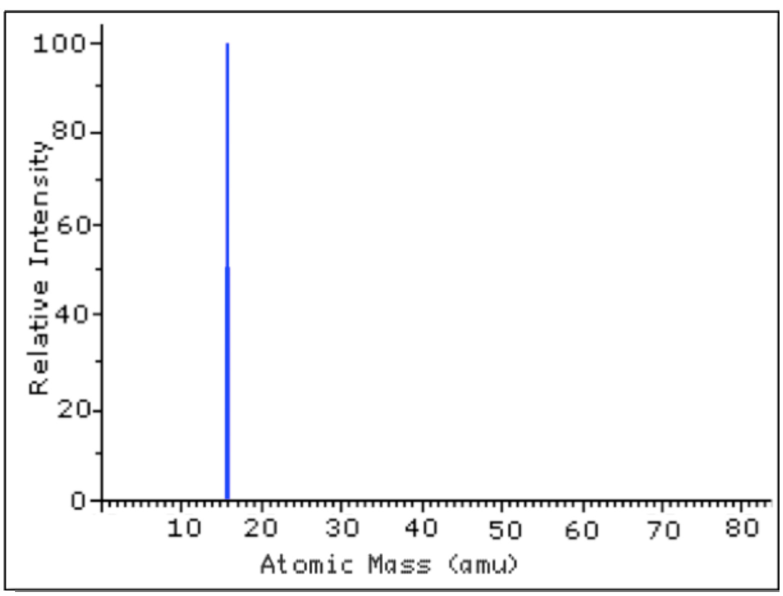
Answer: C

Use a periodic table to identify the element in this mass spectrometer graph:



Answer: sodium

Use a periodic table to identify the element in this mass spectrometer graph:



Answer: oxygen

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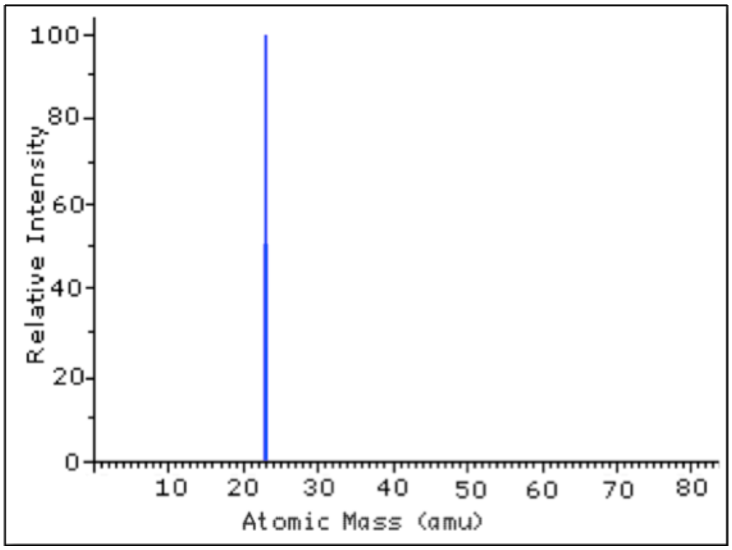
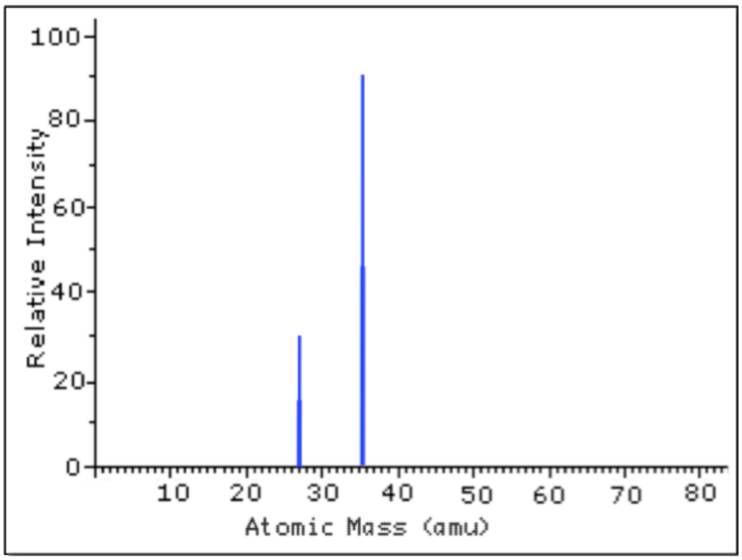
Use a periodic table to identify the element in this mass spectrometer graph:



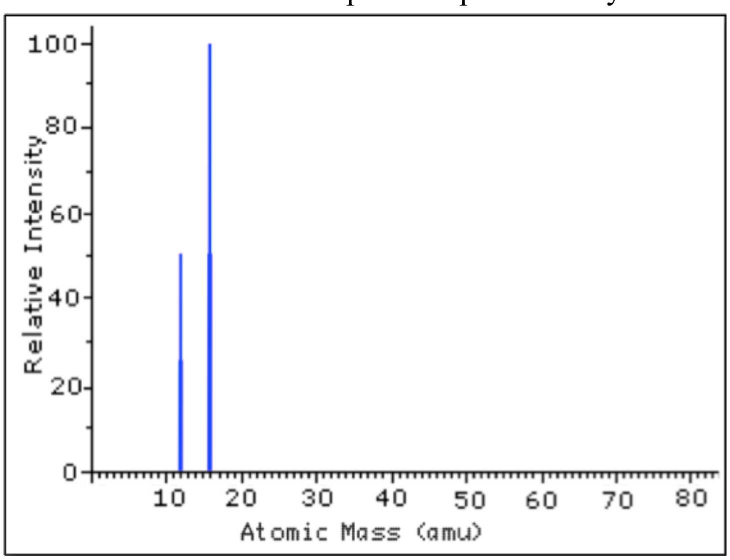
Answer: bromine

Write the formula for the compound represented by this mass spectrometer graph:



Answer: H_2O

Write the formula for the compound represented by this mass spectrometer graph:



Answer: CO_2

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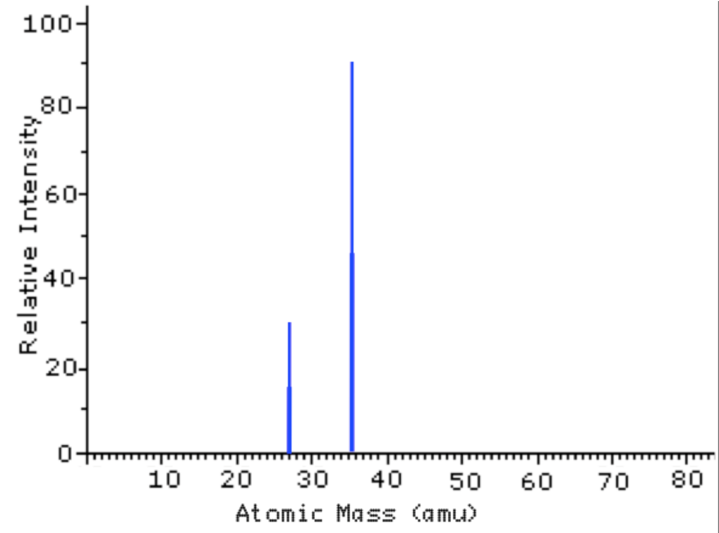
Write the formula for the compound represented by this mass spectrometer graph:



Answer: $AlCl_3$

Directions - Enter coefficients separated by spaces. Type "-" if there is no coefficient

Balance the equation: $NaCl$ + BeF_2 → NaF + $BeCl_2$

Answer: 2 – 2 -

Balance the equation: Al_2O_3 → Al + O_2

Answer: 2 4 3

Balance the equation: CH_4 + O_2 → CO_2 + H_2O

Answer: - 2 - 2

Balance the equation: $KClO_3$ → KCl + O_2

Answer: 2 2 3

Balance the equation: Mg + Mn_2O_3 → MgO + Mn

Answer: 3 – 3 2

Balance the equation: S_8 + O_2 → SO_2

Answer: - 8 8

Level 2

Do cations have a positive of negative charge?

Answer: positive

Do anions have a positive of negative charge?

Answer: negative

What is the valence number for Beryllium?

Answer: +2

What is the valence number for Sodium?

Answer: +1

What is the valence number for Chlorine?

Answer: -1

What is the valence number for Oxygen?

Answer: -2

What is the valence number for iron(III)?

Answer: +3

What is the valence number for mercury(II)?

Answer: +2

What is the valence number for the polyatomic ion sulfite?

Answer: -2

What is the valence number for the polyatomic ion dichromate?

Answer: -2

What is the valence number for the polyatomic ion ammonium?

Answer: +1

What is the valence number for the polyatomic ion cyanide?

Answer: -1

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Write the chemical formula when lithium and sulfur combine?

ANSWER: Li_2S

Write the chemical formula when barium and fluorine combine?

ANSWER: BaF_2

Write the chemical formula when beryllium and nitrogen combine?

ANSWER: Be_3N_2

Write the chemical formula when copper(I) and oxygen combine?

ANSWER: Cu_2O

Write the chemical formula when lead(II) and iodine combine?

ANSWER: PbI_2

Write the chemical formula when magnesium and the polyatomic ion carbonate combine?

ANSWER: $MgCO_3$

Write the chemical formula when calcium and the polyatomic ion chlorate combine?

ANSWER: $Ca(ClO_3)_2$

Write the chemical formula when copper(II) and the polyatomic ion hydroxide combine?

ANSWER: $Cu(OH)_2$

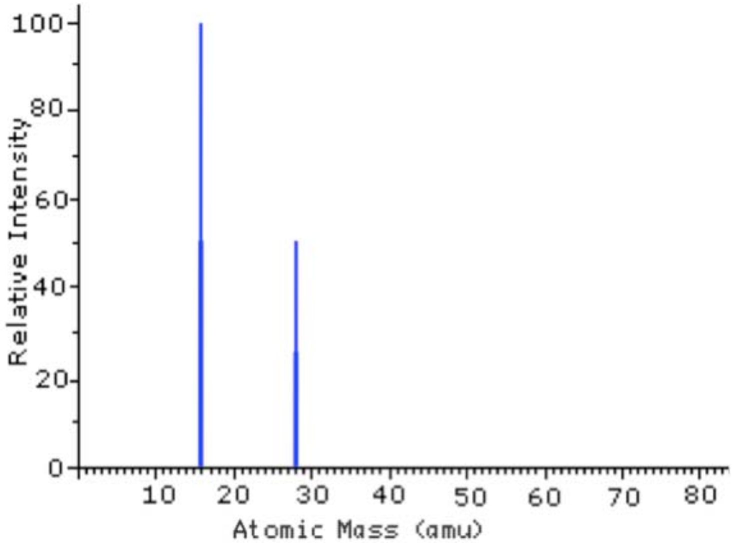
Write the chemical formula when palladium(II) and the polyatomic ion nitrate combine?

ANSWER: $Pd(NO_3)_2$

Write the chemical formula when the polyatomic ions ammonium and chromate combine?

ANSWER: $(NH_4)_2CrO_4$

Write the formula for the compound represented by this mass spectrometer graph:



Answer: SiO_2

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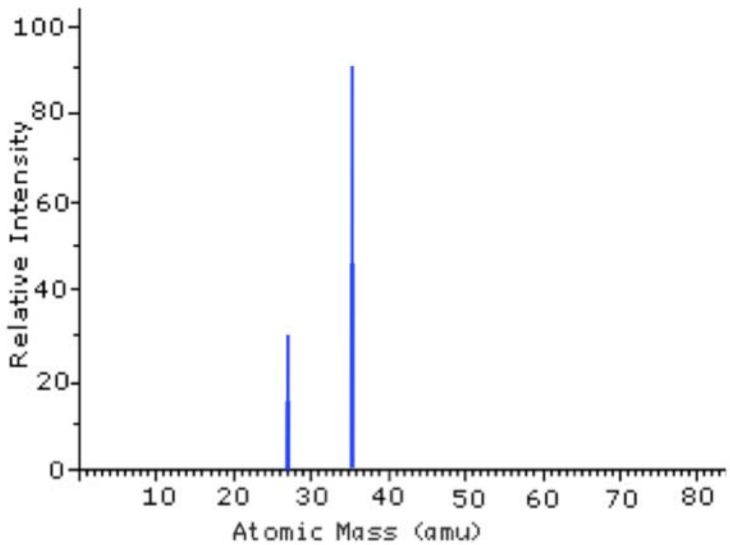
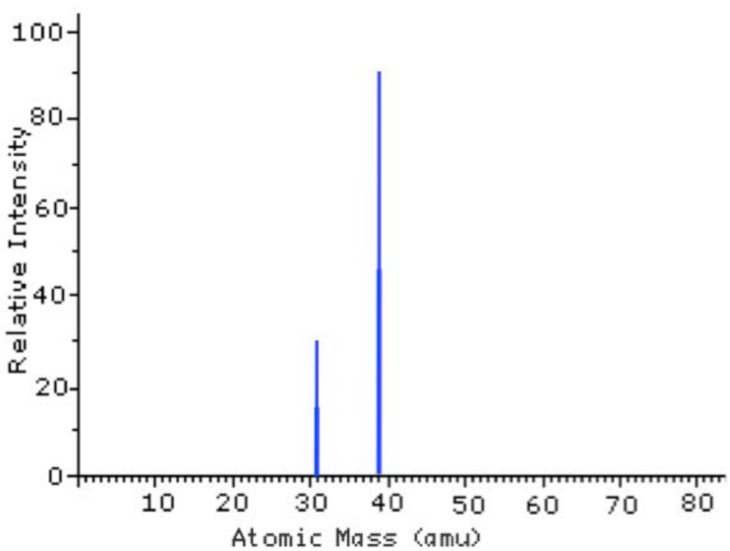


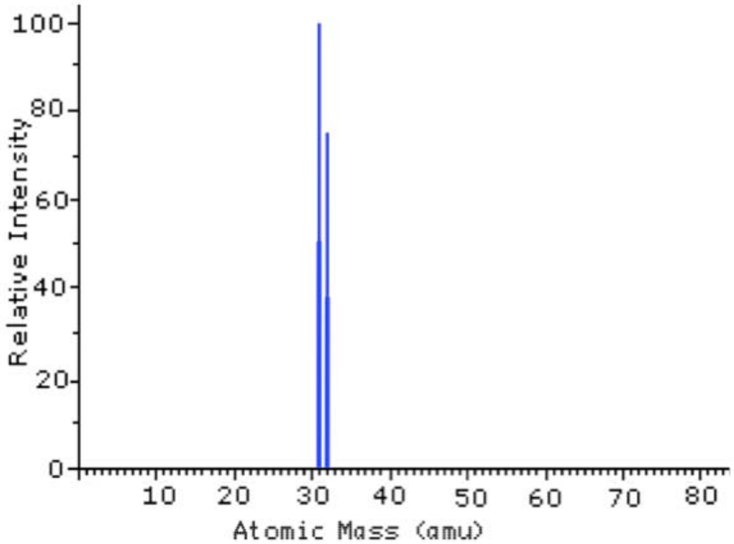
Answer: $AlCl_3$

Write the formula for the compound represented by this mass spectrometer graph:



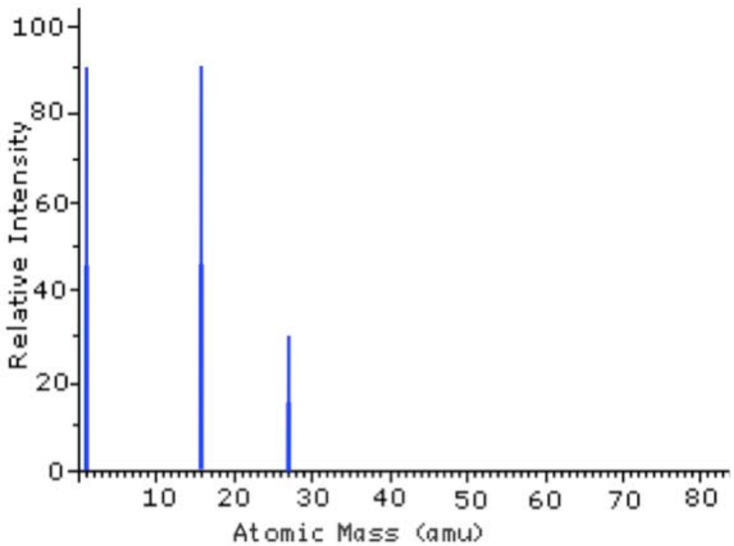
Answer: K_3P

Write the formula for the compound represented by this mass spectrometer graph:



Answer: P_4S_3

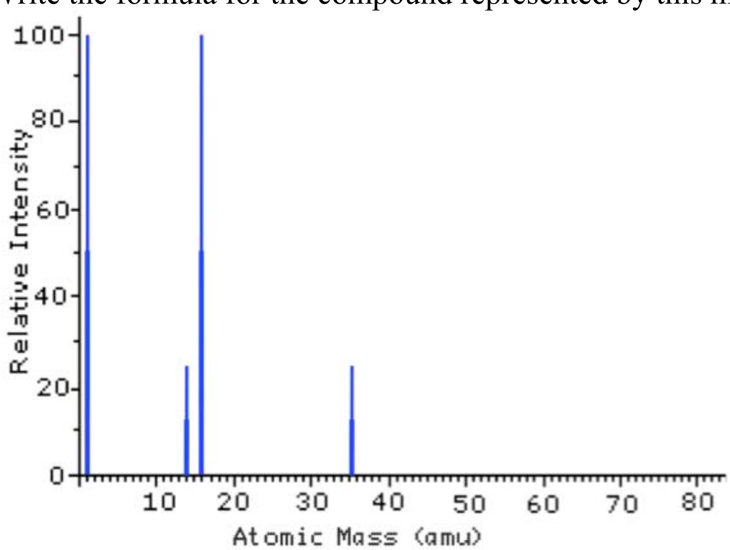
Write the formula for the compound represented by this mass spectrometer graph:



HINT: it contains a polyatomic ion

ANSWER: $Al(OH)_2$

Write the formula for the compound represented by this mass spectrometer graph:



HINT: it contains polyatomic ions

ANSWER: NH_4ClO_4

CASPER Research Experience for Teachers

Directions - Enter coefficients separated by spaces. Type "-" if there is no coefficient

Balance the equation: $SnO_2 + H_2 \rightarrow Sn + H_2O$

ANSWER: - 2 – 2

Balance the equation: $V_2O_5 + HCl \rightarrow VOCl_3 + H_2O$

ANSWER: - 6 2 3

Balance the equation: $NH_4NO_3 \rightarrow N_2 + O_2 + H_2O$

ANSWER: 2 2 - 4

Balance the equation: $N_2 + O_2 + H_2O \rightarrow HNO_3$

ANSWER: 2 5 2 4

Level 3

Write the chemical formula when caesium and carbonate combine?

ANSWER: Cs_2CO_3

Write the chemical formula when chromium(III) and oxygen combine?

ANSWER: Cr_2O_3

Write the chemical formula when germanium(II) and fluorine combine?

ANSWER: GeF_2

Write the chemical formula when magnesium and phosphate combine?

ANSWER: $Mg_3(PO_4)_2$

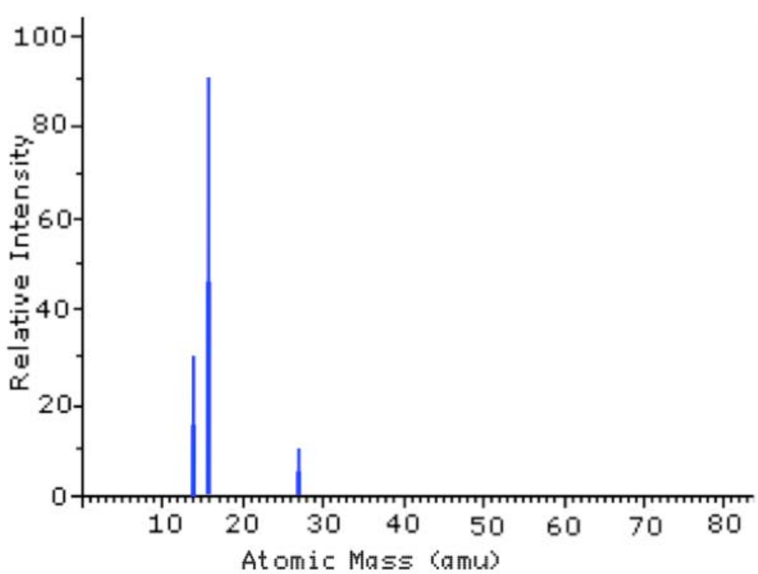
Write the chemical formula when potassium and carbonate combine?

ANSWER: K_2CO_3

Write the chemical formula when lead(II) and nitrate combine?

ANSWER: $Pb(NO_3)_2$

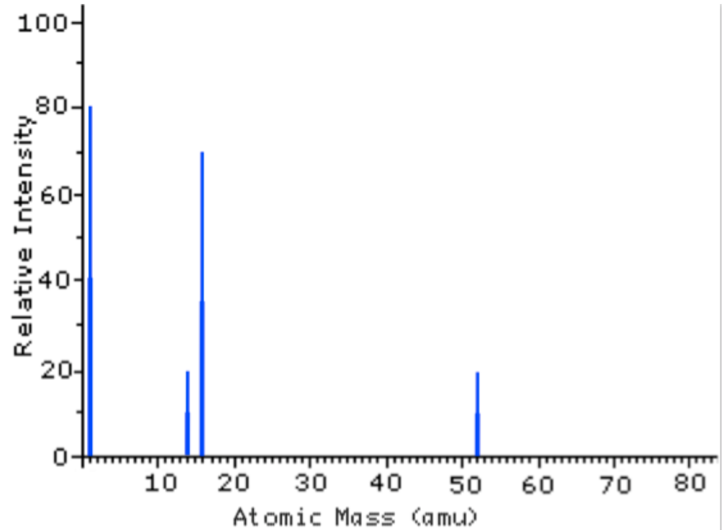
Write the formula for the compound represented by this mass spectrometer graph:



HINT: it contains polyatomic ions

ANSWER: $Al(NO_3)_3$

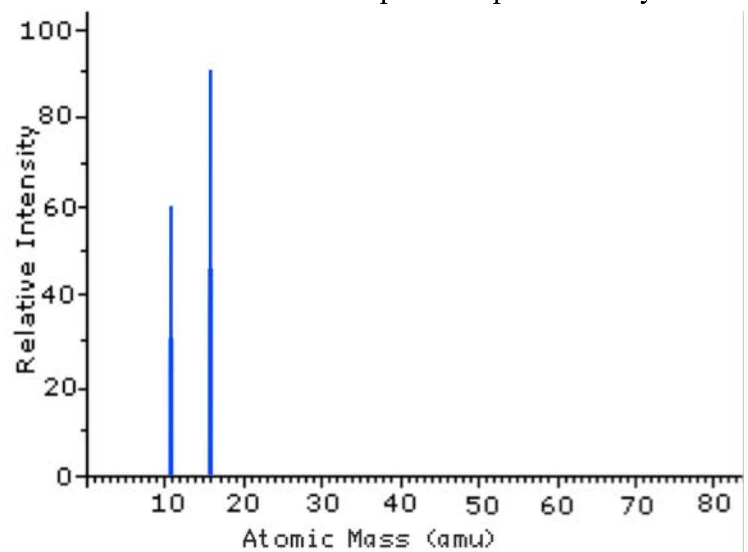
Write the formula for the compound represented by this mass spectrometer graph:



HINT: it contains polyatomic ions

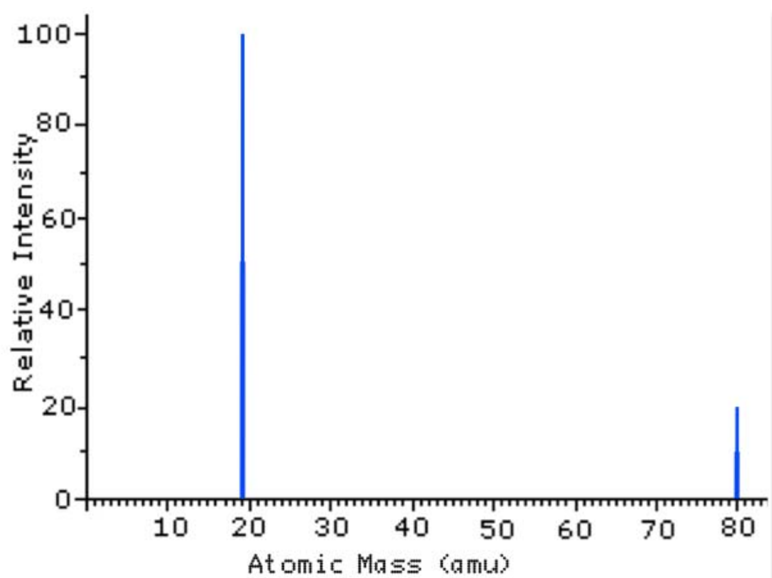
ANSWER: $(NH_4)_2Cr_2O_7$

Write the formula for the compound represented by this mass spectrometer graph:



ANSWER: B_2O_3

Write the formula for the compound represented by this mass spectrometer graph:



ANSWER: BrF_5

CASPER Research Experience for Teachers

Directions - Enter coefficients separated by spaces. Type "**-**" if there is no coefficient

Balance the equation: $AgI + Fe_2(CO_3)_3 \rightarrow FeI_3 + Ag_2CO_3$

ANSWER: 6 – 2 3

Balance the equation: $H_2SO_4 + B(OH)_3 \rightarrow B_2(SO_4)_3 + H_2O$

ANSWER: 3 2 - 6

Balance the equation: $Ba_3N_2 + H_20 \rightarrow Ba(OH)_2 + NH_3$

ANSWER: - 6 3 2

Balance the equation: $FeS + O_2 \rightarrow Fe_2O_3 + SO_4$

ANSWER: 4 7 2 4

What type of reaction is each?

1) $NaOH + KNO_3 \rightarrow NaNO_3 + KOH$ Answer: double replacement

2) $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ Answer: combustion

3) $2\ Fe + 6\ NaBr \rightarrow 2\ FeBr_3 + 6\ Na$ Answer: single replacement

4) $CaSO_4 + Mg(OH)_2 \rightarrow Ca(OH)_2 + MgSO_4$ Answer: double replacement

5) $NH_4OH + HBr \rightarrow H_2O + NH_4Br$ Answer: acid-base

6) $Pb + O_2 \rightarrow PbO_2$ Answer: synthesis

7) $Na_2CO_3 \rightarrow Na_2O + CO_2$ Answer: decomposition

CASPER Research Experience for Teachers

2010 Physics DVD

I made this index when I was converting the DVD into .mp4's to use in my presentation

1	DVD Menu Slide	
2	Text on red wavy background – kinetic energy on door	
3	Text on red wavy background – thermodynamics of coffee	
4	Text on red wavy background – density	
5	Text on red wavy background – balancing equations	
6	Text on red wavy background – parallel and series circuits	
7	Text on red wavy background – You're RIGHT! It was the mascot	
8	1m49s	Security camera footage
9	1h17m43s	? the whole stage show
10	41s	CASPER production
11	CASPER	
12	2m34s	Crime scene with evidence number markers
13	5m25s	Opening scene
14	9m26s	Intro & Breaking the door
15	6m48s	?
16	12m30s	playing with slime
17	12m15s	rubber duck
18	5m14s	circuits
19	2m35s	Scientist in lab coat – Clue 1
20	3m14s	Scientist in lab coat – Clue 2
21	2m46s	Scientist in lab coat – Clue 3
22	3m33s	Scientist in lab coat – Clue 4
23	3m1s	Scientist in lab coat – Clue 5
24		Laser Show
25		Credits

Additional files

Presentation Folder – contains the PowerPoint file and movie files that Danielle Moore and I presented about the Physics Circus

Classroom.pptx - the slides I created and discussed in Steve Rapp & Gar Shetler's presentation about RET research

TarmanPoster2012.ppt – the poster to hang in my classroom

LisaJuly11Red.xlsx - data analysis for my 2 seconds of red laser images

LisaJuly12Green.xtsx – data analysis for my 2 seconds of green laser images

CASPER Research Experience for Teachers

Impact on my teaching

I had an amazing summer immersed in a thriving academic setting. I believe my experience translates into enthusiasm that benefits my students more than those of a teacher that spent their summer by the pool. My urban students don't know a scientist or engineer. I am their closest personal link to a STEM career. The pictures I share and stories I tell, give students a feel for what researchers and graduate students do.

Besides my renewed enthusiasm and rich variety of exposure to actual research, I have real data to bring back to my classroom. I plan to explain and use pictures to show the process I used to gather the data and have my students use Excel spreadsheets to perform the same analysis I did. I know CASPER staff would be willing to interact with my class via Skype or email to answer any questions we have.

I'd like to thank all CASPER faculty and staff for the rewarding professional experience from which I have benefitted greatly. Baylor University is a great place to be.