Virginia Foundation for Agriculture in the Classroom
www.agintheclass.org

AITC Periodic Table Curriculum
Teacher's Guide

This activity guide provides real life examples of how the periodic table is used in the world of agriculture. Lessons provide an opportunity to apply science principles to new technology to ensure the greatest use capital and natural resources.

A tremendous knowledge of science and the periodic table is needed to successfully be a part of the agriculture industry. A basic understanding of element names, symbols, number, and how elements bond together is key to state and national science standards and integrate into the fields of agriculture, biotechnology, aquaculture, plant and animal science, hydroponics, and horticulture. Identifying elements such as nitrogen, which is crucial to plant growth and evaluating the nutrient needs of plant and animal food are just two activities which require a working knowledge of the periodic table.

The AITC Periodic Table also contains information relevant for:

- Demonstrating the concepts of pH value
- Illustrating the nitrogen cycle
- Measuring for water quality
- Identifying acceptable nutrient levels through soil quality testing
- Balancing scientific equations

The activity guide to accompany the Virginia Foundation for Agriculture in the Classroom Periodic Table is one of the resources provided to Virginia classroom teachers attending AITC professional development workshops. The Virginia Foundation for Agriculture in the Classroom is a 501(c)(3) nonprofit organization. The mission of AITC is to promote, through education, an awareness and understanding of the importance of agriculture. Such an understanding will enhance the quality of life and economic well-being of all Virginians.

AITC acknowledges the contributions of our primary writer Gail Clark. Gail is a veteran educator with 32 years in public education having served as science instructor at the Commonwealth Governor's School in Stafford County. She and her husband also own and operate a direct market vegetable and beef farm in Stafford, Virginia.

Our gratitude also is extended to Bill Altice who served as the graphic designer for the project. Bill is on staff with the communications department at Virginia Farm Bureau.

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Using the Ag in the Classroom Periodic Table

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Standard of Learning
Science: 6.4, PS 2, PS 3, PS 4, ES 5, CH 2, CH 3

Objective
The student will:

- Use the AITC Periodic Table to determine the number of protons, electrons, and neutrons in a variety of elements found on a beef mineral mix feed tag.
- Use the AITC Periodic Table to describe the metal/nonmetal characteristic of these elements.
- Use the AITC Periodic Table to draw Bohr models of a number of elements.
- Use the AITC Periodic Table to determine the neutrons in a variety of medically useful isotopes.
- Have access to summary information concerning bonding, periodic trends, and electron shells.

Materials
AITC Periodic Table, Background Information, and student worksheets (AITC Periodic Table – Practical Application)

Background Knowledge
The background knowledge is given in the next several pages. It is formatted to be used either as teacher background material or as a student handout. The information covers material about the Periodic Table: obtaining information about each element, isotopes, the families/groups (columns), the periods (rows), the Bohr model and energy levels, ionic bonding, covalent bonding, and periodic trends. The student worksheet uses the ingredient label from a beef cattle mineral mix to show the practical use of some elements. It is these elements, then, which are used to practice finding numbers of protons, neutrons, and electrons; identifying groups and metal/nonmetal and drawing Bohr models. There are a few extension questions asked, just for discussion and reading comprehension. Finally, there is a worksheet on isotopes which gives the student some examples of the uses of isotopes, while giving them the opportunity to practice finding the number of neutrons in various isotopes.

The Periodic Table of the Elements represents an attempt to visually organize all of the elements into an orderly chart which emphasizes patterns of chemical reactivity. Each block gives four pieces of information about an element, but the location of that block tells even more about the structure of each atom of that element and how it reacts with other atoms.

Information from each element box:

7
N
Nitrogen
14.00

7 – This is the **ATOMIC NUMBER**. Notice that atomic numbers increase as you move horizontally across each period (row). The atomic number represents the number of **PROTONS** (positively charged particles) in the nucleus.

N – This is the **SYMBOL** of the element. Notice that the first letter of the symbol is ALWAYS in upper case and the second letter of the symbol (if there is one) is ALWAYS written in lower case (example: zinc is Zn).

Nitrogen – This is the **NAME** of the element. Some of the elements have been known for thousands of years and others are being made today by man in accelerators. Notice that some of the symbols match well with the element names (N for nitrogen), but others don't make sense (Cu for copper, Au for gold). This is because some symbols are derived from the old, Latin names of the elements (cuprous for copper and aurora for gold).

14.00 – This is the **AVERAGE ATOMIC MASS** of one atom of the element in a.m.u., or atomic mass units. The mass of an atom of an element is made up of the protons and **NEUTRONS** (particles which carry no charge) in the nucleus and the negligible mass of the **ELECTRONS** (negatively charged particles) in energy shells around the outside of the nucleus. Not all atoms of one type of element have the same mass, since some atoms may have more neutrons than others. Atoms which have the same number of protons, but different numbers of neutrons are called **ISOTOPES** (Example: Carbon – 12 and Carbon – 14). The atomic mass of an element is calculated by averaging the masses of these isotopes. Weighing one atom of an element is not practical in the laboratory, so chemists use a larger number of atoms to create masses which can actually be measured out on a regular scale. The mass of 6.02×10^{23} (called Avagadro's number or a **MOLE**) atoms of an element is the atomic mass in grams. So a mole of nitrogen atoms weighs 14.00 grams.

The number of neutrons in an atom is calculated by subtracting the atomic number from the atomic mass. (Example: Nitrogen 14 – 7 = 7 neutrons.).
In a neutral atom, there are the same numbers of electrons as there are protons. (Nitrogen has 7 protons and 7 electrons).

Families on the Periodic Table

Across the top of the periodic table, find the number 1 – 18, labeling each column. These columns are called **GROUPS or FAMILIES**. The elements in these families have similar chemical properties. Arranging the elements by atomic number (smallest to largest) is fundamental in determining its chemical properties.

Group 1 – Alkali Metals – Li, Na, K, Rb, Cs, Fr – These are highly reactive metals which have 1 electron in their outer shell which can be easily pulled away leaving 1 more proton than electrons. This means they make ions with a +1 charge. Ions with a positive charge are called **CATIONS**. Hydrogen is shown atop lithium, but hydrogen is not a metal. It has one electron in its only shell, which is often pulled away, leaving the cation H^+.

Group 2 – Alkaline Earth Metals (Alkaline metals) – Be, Mg, Ca, Sr, Ba, Ra – These metals have 2 electrons in their outer shells which can be pulled away leaving the atom with 2 more protons than electrons. This means they make ions with a +2 charge.

Groups 3 – 12 – the Transition Metals – These metals are characterized by elements which can make more than one type of ion. The rare earth metals, which are atomic numbers 58 -71 and 90 – 103, really should be inserted between families 3 and 4. However, this would make the periodic table too long, so for convenience of printing, the Lanthanide Series and Actinide Series are given their own name and placed below the rest of the Periodic Table.

Group 13 elements– B, Al, Ga, In – These metals and metalloids produce ions with a charge of +3.

Groups 14 -15 elements – These metalloids, metals and non-metals may form either ionic bonds or covalent bonds, depending on the element.

Group 16 elements – the Chalcogens – O, S, Se, Te, Po – These highly reactive non-metals and metalloids can form either ionic or covalent bonds. Ions can be formed when two additional electrons are added to complete their outer shell. This leaves the atom with two more electrons than protons, thus creating an atom with an overall -2 charge. Negatively charged ions are called **ANIONS**.

Group 17 elements – the Halogens – F, Cl, Br, I, At – These non metals only need one electron to fill their outer shell, forming ions with a charge of -1. These are also highly reactive elements.

Group 18 elements– the Nobel gases – Ne, Ar, Kr, Xe, Rn – With a few exceptions, these are inert gases which have completed outer shells.

Periods on the Periodic Table

Down the sides of the Periodic Table are the numbers 1 – 7 which number each row. These rows are called **PERIODS** and represent the **ELECTRON SHELLS** or **ENERGY LEVELS** which encircle the nucleus of each atom. These electron shells are where the electrons are found. In the Bohr model of the atom, these shells are drawn as circles around the nucleus with electrons drawn on the shell line. This type of model makes the atom resemble a small solar system. This is the type of model students usually draw because it is easy to do on paper. However, these shells, or energy levels really represent clouds which are areas where the electrons most probably are located. Picture the nucleus as a pea, energy level 1 as a ping pong ball surrounding the pea, energy level 2 as a tennis ball surrounding the ping pong ball and the pea, etc. The electrons could be anywhere on the surface of each ball. Actually the energy levels have more complex shapes than this, but this model provides a three dimensional mental picture which is a bit more accurate than the two dimensional Bohr model.

Each of the electron shells can hold a certain number of electrons. Mathematically this is expressed as $2n^2$, where n=period number. The closer the energy level is to the nucleus, the more strongly the electrons (with a negative charge) are attracted to the nucleus (with a positive charge). Energy level 1 is the closest to the nucleus, but can hold only 2 electrons. These periods, or shells, are also referred to by letters: K, L, M, N, O. As the electrons get farther from the nucleus, their specific positions relative to the nucleus get more complex and complicated, but for the first few periods the following chart usually holds true:

Period, Energy Level, Electron Shell, *n*	Letter designation	Maximum number of electrons in shell $2n^2$
1	K	$(2)(1)^2 = 2$
2	L	$(2)(2)^2 = 8$
3	M	$(2)(3)^2 = 18$
4	N	$(2)(4)^2 = 32$

Look at the front of the AITC Periodic Table. Find the picture of the Bohr Model of Nitrogen. Notice that the blue + spheres represent the protons, the red spheres represent the neutrons (there was only enough room in the drawing to show four of these), and the small – spheres represent the electrons. Using the sample Nitrogen, we now know the following:

Nitrogen :

- Atomic number = 7
- Atomic mass = 14
- 7 protons
- 7 electrons
- 14-7 = 7 neutrons
- Nucleus contains the 7 protons and the 7 neutrons
- Energy Levels contain 7 total electrons: K = 2, L = 5
- Number of spaces left to complete the L shell is 8 – 5 = 3

IONIC BONDING

Knowing how many spaces are left in the outside shell is important in understanding the chemistry of making ionic compounds. It is well known that opposites attract. In chemistry, cations (positive atoms) are attracted to anions (negatively charged atoms) which results in an ionic bond. In addition, atoms are most stable when their outer shell is completely full. Atoms will form ions in order to achieve this stability. However, they form an ion by expending the LEAST amount of energy. Sometimes this means giving off one or more electrons and sometimes this means gaining one or more electrons. Watch what happens to sodium and chlorine.

Element and Symbol	Atomic number – # of protons and # of electrons	Electron distribution	Action needed to most easily complete an outside shell, using the LEAST amount of energy.	Charge when a full outside shell is created
Sodium – Na	Atomic #11: 11 protons, 11 electrons	K =2 L =8 M =1	Giving up 1 electron easily leaves a full L shell (more energy required to gain 17 electrons and complete M)	+1 (11 protons and 10 electrons)
Chlorine – Cl	Atomic #17: 17 protons, 17 electrons	K =2 L =8 M =7	As a halogen with higher electronegativity and ionization energy, it takes less energy to gain 1 electron than to release 7	-1 (18 electrons and 17 protons)

So now Na = +1 and Cl = -1. Remember opposites attract! And these charges are equal and opposite, so one sodium ion is attracted to one chlorine ion. That gives us the chemical compound NaCl, or sodium chloride – SALT!! Salt is an ionic compound. Ionic bonding happens between a metal (sodium) and a non-metal (chlorine) when electrons are transferred from one atom to another. This type of bonding is fairly weak and the two ions separate easily when the compound is dissolved in water.

COVALENT BONDING

Sometimes, instead of electrons being actually transferred from one atom to another as in the case of ionic bonding, electrons are only shared. This results in covalent bonding. Covalent bonding is prevalent when non-metals combine with non-metals. It is also the kind of bonding which results in diatomic molecules. Diatomic molecules are those which consist of two of the same type of atom. There are seven gaseous non-metals which exist naturally as diatomic molecules: H_2, N_2, O_2, F_2, Cl_2, Br_2, and I_2. (NOTE: Take a look at the Periodic Table. With the exception of hydrogen, the blocks of the seven elements form the number seven by their position in the Periodic Table, so it is always easy to find them!)

In covalent bonding, two electrons, one electron from each atom, team up to form an electron pair. This pair of electrons spends some time orbiting around each of the nuclei. The two electrons are jointly held by the two nuclei. This covalent bond is extremely strong and takes a great deal of energy to break. In addition to the diatomic molecules, examples of covalent bonding are found in water (H_2O) and carbon dioxide (CO_2).

PERIODIC TRENDS

The organization of the Periodic Table allows the user to predict how an element will act based on its location within the table. There are patterns which emerge as the chart is read going left to right across a period, as well as top to bottom, going down each group or family.

As the elements are read from left to right going across a period:

- The nuclear charge (atomic number) increases
- The atomic radii decreases
- The electronegativity increases
- The ionization energy increases

As the elements are read from top to bottom down a group:

- The nuclear charge (atomic number) increases
- The atomic radii increases
- The electronegativity decreases
- The ionization energy decreases

The **ATOMIC RADIUS** is half the distance between the nuclei of two of the same type of atom (the diatomic molecules). From left to right the atomic radius decreases because as the atomic number increases, the additional electrons are being pulled closer to the nucleus, while staying in the same energy level. Going down a period, the atomic radius increases because electrons are being added to larger energy levels, which are farther from the nucleus.

ELECTRONEGATIVITY measures the strength of the attraction that an atom has for its electrons in its outermost shell. Going left to right along a row, the electronegativity increases since the larger nuclear charge is pulling the electrons in more forcefully. Flourine, in the upper right hand corner of the Periodic Table, has the largest electonegativity (4.0) and is the most chemically active nonmetal. In the lower left hand corner of the Periodic Table are cesium and francium with the lowest electronegativity (.7). These are highly reactive metals.

IONIZATION ENERGY is the energy required to remove an electron from a gaseous atom or ion. Going left to right, this increases. This makes sense. The electonegativity is increasing, meaning that the electrons are being held tighter. Therefore, it takes more energy to pull an electron away from the atom. Go back to the example in ionic bonding section. Chlorine has 7 electrons in the outer shell and sodium has 1 electron in the outer shell. It would take much more energy to take an electron away from chlorine than sodium.

Procedure

Complete worksheet packet using the periodic table

Answer Keys

Ag in the Classroom's Periodic Table – Practical Application

Element Name	Symbol	Atomic #	Atomic Mass	# Protons	# Electrons	# Neutrons	96%,3.7% or .3%?
Calcium	Ca	20	40.08	20	20	20	3.7
Phosphorus	P	15	30.97	15	15	15 or 16	3.7
Magnesium	Mg	12	24.31	12	12	12	3.7
Manganese	Mn	25	54.94	25	25	29 or 30	3.7
Copper	Cu	29	63.55	29	29	34 or 35	.3
Selenium	Se	34	78.96	34	34	44 or 45	.3
Zinc	Zn	30	65.41	30	30	35	.3
Iodine	I	53	126.90	53	53	73 or 74	.3
Cobalt	Co	27	58.93	27	27	31 or 32	.3

MINERAL FEED TAG EXTENSIONS:

1. If your cow herd is being fed hay and a balanced grain formula during the winter in a barn lot, would you use this mineral supplement? (No) Why or why not? The directions state that cattle should be grazing when this mineral is fed.

2. What is an ionic compound given in the ingredient list?

Salt (NaCl)

3. Often these mineral mixtures are called TRACE MINERAL SUPPLEMENTS. Why might the word "trace" be used?

A very small amount that is not measured in another manner. None of these elements makes up more than 3.7% of an organism.

4. What does the unit "ppm" stand for?

Parts per million

5. The unit "IU" stands for International Unit. Do you think 1 IU is a large amount or a small amount? Why?

IU stands for International Units and is used for the measurement of drugs and vitamins. The IU is dependent on the potency of the substance, and each substance would have a different IU to milligram conversion. The applications from the Mineral for Beef Cattle label note IU/lb. Students should reference this in there opinion statement regarding amount size.

6. If you had a group of lambs you were feeding out on winter oat pasture would you use this mineral supplement? (No) Why or why not? The directions state that using this mineral supplement will cause copper toxicity.

Using the same elements from the mineral list, give the name of the element, name the group it is in, list its period number, and tell whether it is a metal or a nonmetal.

Element name	Group number and name	Period number	Metal or nonmetal
Calcium	2, alkaline earth metals	4	Metal
Phosphorus	15, nonmetals	3	Nonmetal
Magnesium	2, alkaline earth metals	3	Metal
Manganese	7, transition metals	4	Metal
Copper	11, transition metals	3	Metal
Selenium	16, nonmetals	4	Nonmetal
Zinc	12, transition metals	4	Metal
Iodine	17, halogens	5	Nonmetal
Cobalt	9, transition	4	Metal

Calcium isotopes are used in clinical research in nutrition studies to find out about the absorption amounts and rates of calcium in the body.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
Ca-42	20	42	20	22
Ca- 48	20	48	20	28
Ca as given in Periodic Table	20	40.08	20	20

Magnesium isotopes are also used in absorption studies, but are also used to investigate heart disease.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
Mg – 25	12	25	12	13
Mg – 26	12	26	12	14
Mg as given in Periodic Table	12	24.31	12	12

Stable and naturally occurring isotopes of copper are Cu-63 and Cu-65. Cu-64 is produced industrially for cancer diagnosis and treatment.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
Cu- 64	29	64	29	35
Cu – 65	29	65	29	36
Cu as given in Periodic Table	29	63.55	29	34

There are at least 37 different isotopes of Iodine. Many of these are used as radioisotopes in nuclear medicine. Positron Emission Tomography (PET scans), use I-124.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
I – 124	53	124	53	71
I – 131	53	131	53	78
I as given in Periodic Table	53	126.90	53	73 or 74

Using the Periodic Table
Real Life Decisions

Directions: Look at the ingredient list for this beef cattle mineral mix. Included in this mixture are nine elements which are essential for plant and animal life. Fill in the chart below with the name of the element, correct chemical symbol, atomic number, atomic mass, number of protons, number of electrons, and number of neutrons. Look on the back of the AITC Periodic Table and tell whether this element is in the group which makes up 96%, 3.7% or .3 % of living organisms.

A Free Choice Mineral for Beef Cattle

GUARANTEED ANALYSIS
Calcium, minimum………… 13.0%
Calcium, maximum………… 15.0 %
Phosphorus, minimum……… 4.0%
Magnesium, minimum………11.0%
Salt, minimum………………11.5%
Salt, maximum………………13.5%
Manganese, minimum…… 4000 ppm
Copper, minimum……….. 1500 ppm
Selenium, minimum…………26 ppm
Zinc, minimum……………4000 ppm
Iodine, minimum………….. 100 ppm
Cobalt, minimum………… 30 ppm
Vitamin A, minimum… 175,000 IU/lb
Vitamin D, minimum…..45,000 IU/lb
Vitamin E, minimum……. 150 IU/lb
FOR FEEDING INSTRUCTIONS SEE BACK OF LABEL.

CAUTION: Consumption of this product by sheep may result in copper toxicity.
INSTRUCTIONS FOR FEEDING:
Feed beef cattle mineral on a free choice basis. Do not offer any other mineral or salt during the time you are feeding this mineral. Average consumption will be approximately 4 ounces daily depending on body weight and range conditions.
This mineral should be fed to cattle grazing on green winter pastures such as oats, rye and wheat and to cattle grazing on immature native summer grasses.
CAUTION: Follow feeding directions. Four (4) ounces of this product will supply 3 mg of selenium. Consumption of selenium should not exceed 3 mg daily.
CAUTION: Consumption of this product by sheep my result in copper toxicity.

Element Name	Symbol	At. #	Atomic Mass	# Protons	# Electrons	# Neutrons	96%,3.7% or .3%?

MINERAL FEED TAG EXTENSIONS

6. If your cow herd is being fed hay and a balanced grain formula during the winter in a barn lot, would you use this mineral supplement? Why or why not?

7. What is an ionic compound given in the ingredient list?

8. Often these mineral mixtures are called TRACE MINERAL SUPPLEMENTS. Why might the word "trace" be used?

9. What does the unit "ppm" stand for?

10. The unit "IU" stands for International Unit. Do you think 1 IU is a large amount or a small amount? Why?

6. If you had a group of lambs you were feeding out on winter oat pasture would you use this mineral supplement? Why or why not?

Using the same elements from the mineral list, give the name of the element, name the group it is in, list its period number, and tell whether it is a metal or a nonmetal.

Element name	Group number and name	Period number	Metal or nonmetal

On another sheet of paper, draw Bohr models of the following elements: calcium, phosphorus, magnesium, and chlorine.

ISOTOPES – Most elements have multiple isotopes – atoms with the same number of protons, but differing numbers of neutrons. These different forms of the same element are often listed in this form: Symbol-atomic mass. For example, carbon 14 is an isotope used to measure the age of ancient fossils. It would be written as C-14. The atomic number of carbon is 6. To find the number of neutrons in C-14, subtract the atomic number from the atomic mass: 14 – 6 = 8. Several isotopes are listed below, along with some of their uses. For each isotope, give its atomic number, atomic mass, number of protons and number of neutrons.

Calcium isotopes are used in clinical research in nutrition studies to find out about the absorption amounts and rates of calcium in the body.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
Ca-42				
Ca- 48				
Ca as given in Periodic Table				

Magnesium isotopes are also used in absorption studies, but are also used to investigate heart disease.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
Mg – 25				
Mg – 26				
Mg as given in Periodic Table				

Stable and naturally occurring isotopes of copper are Cu-63 and Cu-65. Cu-64 is produced industrially for cancer diagnosis and treatment.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
Cu- 64				
Cu – 65				
Cu as given in Periodic Table				

There are at least 37 different isotopes of Iodine. Many of these are used as radioisotopes in nuclear medicine. Positron Emission Tomography (PET scans), use I-124.

Isotope	Atomic #	Atomic mass	# of protons	# of neutrons
I – 124				
I – 131				
I as given in Periodic Table				

Balancing Agricultural Equations

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Standard of Learning
Science: LS 6, PS 5, BIO3, CH3

Objective
The student will:
- Balance chemical equations using agricultural examples and the periodic table

Materials
AITC Periodic Table to be used as reference, student worksheet

Background Knowledge

Balancing equations – Students usually enjoy balancing equations since it can often seem like puzzle solving. However, aiding the students with a few strategies is often helpful. Drawing a vertical line at the arrow in the equation and keeping a tally of element counts on both the reactant and the product sides is a very visual, useful accounting system for beginning science students. Remind students that when balancing equations that subscripts can NEVER be changed – only COEFFICIENTS. Also show them that polyatomics in parentheses need to be multiplied out by the subscript (EX: $(NO_3)_2$ means there are 1 x 2 = 2 nitrogen atoms and 3 x 2 = 6 oxygen atoms.) Then have students begin by balancing the metals, with hydrogen and oxygen coming LAST.

Reaction Types – Students often are asked to look at an equation and determine the type of reaction which is taking place. Simple reaction types which they should be able to identify include the following:

Single replacement: A + BC → B + AC (the metal A replaces the metal B in the binary compound)
Double replacement: AB + CD → AD + CD (the metals A and C switch places in two binary compounds)
Synthesis: A + B → AB (a compound AB is made by the chemical bonding of two elements A and B)
Decomposition: AB → A + B (the bonds of a binary compound AB are broken to form the two elements A and B)
Neutralization: acid + base → an ionic salt + water (EX: HCl + KOH → KCl + H_2O or hydrochloric acid + potassium hydroxide → potassium chloride (an ionic salt) + water); a gas such as CO_2 can also be a product.

Procedure
1. **Water is a requirement for all of life. It can be made in the atmosphere from diatomic molecules of atmospheric oxygen and hydrogen.**

____2__ H_2 + __1___ O_2 → __2____ H_2O

Answer: 2 hydrogen + 1 oxygen → 2 water The tally is H:4, O:2

What type of reaction is this? SYNTHESIS

2. **Nitrogen is often supplied to fertilizer in the form of ammonia or anhydrous ammonia. One way to make ammonia is by the Haber process. Balance the equation showing the Haber process and name each reactant and product.**

__1_ N_2 + _3_ H_2 → __2__ NH_3

ANSWER:

1 nitrogen + 3 hydrogen → 2 ammonia (or nitrogen trihydride) BALANCING HINTS: With two nitrogen on the left, a multiple of 2 is required on the ammonia on the right. Always start with the lowest possible numbers – in this case 1 molecule of atmospheric nitrogen and 2 molecules of ammonia. This gives 2 x 3 or 6 hydrogen on the right. To get 6 hydrogen on the left means using 6/2 or 3 molecules of atmospheric hydrogen. If you are using a tally chart, the total number of each atom is as follows: N = 2; H = 6

WHAT TYPE OF REACTION IS THIS? Synthesis

3. **Phosphoric acid is used as the source of phosphorus in the manufacture of fertilizer. Balance the equation and name each of the reactants and products**:

__1_ $Ca_3(PO_4)_2$ + _3_H_2SO_4 → _2_H_3PO_4 + __3_$CaSO_4$

ANSWER:

1 Calcium phosphate + 3 sulfuric acid → 2 phosphoric acid + 3 calcium sulfate – BALANCING HINTS: the three calciums on the left mean that there need to be at least 3 $CaSO_4$ molecules. That makes 3 sulfate units on the right, which requires 3 sulfate units on the left, meaning 3 sulfuric acid molecules. Having 2 phosphate units on the left means that two phosphate units are needed on the right, which requires a coefficient of 2 on the phosphoric acid. If you are using a tally chart, the total number of each atom are as follows: Ca = 3; P = 2; S = 3; O = 20; H = 6

WHAT TYPE OF REACTION IS THIS? Double replacement

4. **Farmers often add lime to their crop fields and pastures to reduce the acidity of farmland. This lime is supplied in the form of calcium carbonate, otherwise known as limestone. Balance the equation below and name each reactant and product.**

_2__ HCl + _1_ $CaCO_3$ → _1_ H_20 + __1 CO_2 + _1_ $CaCl_2$

ANSWER:

2 hydrochloric acid + 1 calcium carbonate → 1 water + 1 carbon dioxide + 1 calcium chloride BALANCING HINTS: When students see oxygen in more than one product, tell them to balance the oxygen LAST. Start with the calcium here. One calcium on the left in the calcium carbonate can be balanced with one molecule of calcium chloride on the right. One calcium chloride on the right requires 2 hydrochloric acids on the left to balance the chlorine. That results in 2 hydrogens on the left which requires 1 water on the right. One calcium carbonate on the left results in one carbon on the left which can be balanced with 1 carbon dioxide on the right. The oxygens balance. Using a tally chart gives hydrogen = 2; chlorine = 2; calcium = 1; carbon = 1; oxygen = 3

WHAT TYPE OF REACTION IS THIS? Neutralization.

REMEMBER THAT I N THESE REACTIONS AN ACID AND A BASE FORM WATER AND AN IONIC SALT. IN THIS REACTION WHAT IS THE BASE? Calcium carbonate WHAT IS THE ACID? HCl, hydrochloric acid or hydrogen chloride WHAT IS THE SALT? Calcium chloride

5. **Photosynthesis is an endergonic reaction which requires the energy input from the sun to proceed. The glucose made from this reaction is used to fuel cellular respiration in plants and animals. During photosynthesis, green plants are able to "fix" carbon from the atmosphere and incorporate it into the food web. Balance the equation for photosynthesis below and name each reactant and pr**oduct.

Sun

_6__ CO_2 + _6_ H_2O → __1_ $C_6H_{12}O_6$ + _6__ O_2

ANSWER: 6 carbon dioxide + 6 water → 1 glucose + 6 oxygen BALANCING HINTS: With oxygen in each compound, students should leave the oxygen for LAST. Start with either the carbon or the hydrogen. Look at the glucose on the right. To balance the 6 atoms of carbon on the right requires 6 molecules of carbon dioxide on the left. Also, to balance the 12 hydrogen in one molecule of glucose on the right requires 12/2 = 6 molecules of water on the left. Now add all the oxygen on the left. There should be 6x2 = 12 oxygen in the carbon dioxide plus 6x1 = 6 oxygen in the water. That is a total of 18 oxygen atoms on the left. Over on the right, the one molecule of glucose has used up 6 atoms of oxygen, meaning there need to be 18 – 6 = 12 atoms of oxygen on the right. Since atmospheric oxygen is always a diatomic molecule (two oxygen atoms bonded together – O_2), 12/2 = 6 molecules of atmospheric oxygen are required on the right. Using a tally chart reveals C=6; O = 18; H= 12. Note that photosynthesis as a reaction only takes place in plants, but the glucose produced from photosynthesis is used in cellular respiration in both plants and animals.

6. **Respiration is an exergonic reaction (producing energy) which occurs in all plant and animal cells. This is how ATP, the energy molecule is made. Balance the equation for respiration below and name each reactant and product**.

_1__ $C_6H_{12}O_6$ + _6__ O_2 → _6__ CO_2 + __6__ H_20 + energy (ATP + heat)

ANSWER: 1 glucose from photosynthesis + 6 oxygen from the atmosphere → 6 carbon dioxide released into the atmosphere + 6 water + energy (ATP + heat) BALANCING HINTS – see the equation describing photosynthesis. Note that energy is not counted in equations. The ATP formed and heat released are a result of bonds changing as a phosphate group is added to ADP forming ATP – adenosine diphosphate being changed into adenosine triphosphate.

Compare and contrast equations 5 and 6.
ANSWER: These are called coupled reactions. The products of one reaction are the reactants of the other reaction. Photosynthesis is endergonic (it requires outside energy), whereas respiration is exergonic (it produces extra energy). Photosynthesis is also called an anabolic reaction, since it synthesizes carbohydrates (in the example equation above glucose is used as the carbohydrate). Respiration is called a catabolic reaction, since it breaks down the carbohydrate.

Balancing Agricultural Equations Worksheet

1. Water is a requirement for all of life. It can be made in the atmosphere from diatomic molecules of atmospheric oxygen and hydrogen. **Balance** the equation and **name** each reactant and product.

   ______ H_2 + _____ O_2 → ______ H_2O

WHAT TYPE OF REACTION IS THIS?

2. Nitrogen is often supplied to fertilizer in the form of ammonia or anhydrous ammonia. One way to make ammonia is by the Haber process. **Balance the equation** showing the Haber process and **name each** reactant and product.

   ____ N_2 + ___ H_2 → ____ NH_3

   WHAT TYPE OF REACTION IS THIS?

3. Phosphoric acid is used as the source of phosphorus in the manufacture of fertilizer. **Balance the equation and name** each of the reactants and products:

   ____ $Ca_3(PO_4)_2$ + ____H_2SO_4 → ___H_3PO_4 + ____$CaSO_4$

   WHAT TYPE OF REACTION IS THIS?

4. Farmers often add lime to their crop fields and pastures to reduce the acidity of farmland. This lime is supplied in the form of calcium carbonate, otherwise known as limestone. **Balance the equation below and name** each reactant and product.

   ____ HCl + ___ $CaCO_3$ → ___ H_20 + ___ CO_2 + ___ $CaCl_2$

WHAT TYPE OF REACTION IS THIS? REMEMBER THAT IN THESE REACTIONS AN ACID AND A BASE FORM WATER AND A SALT. IN THIS REACTION WHAT IS THE BASE? WHAT IS THE ACID? WHAT IS THE SALT?

5. Photosynthesis is an endergonic reaction which requires the energy input from the sun to proceed. The glucose made from this reaction is used to fuel cellular respiration in plants and animals. During photosynthesis, green plants are able to "fix" carbon from the atmosphere and incorporate it into the food web. **Balance** the equation for photosynthesis below and **name each** reactant and product.

$$\_\_\_\_ CO_2 + \_\_\_ H_2O \xrightarrow{\text{sun}} \_\_\_\_\_ C_6H_{12}O_6 + \_\_\_\_ O_2$$

6. Respiration is an exergonic reaction which occurs in all plant and animal cells. This is how ATP, the energy molecule is made. **Balance** the equation for respiration below and **name** each reactant and product.

$$\_\_\_\_ C_6H_{12}O_6 + \_\_\_\_ O_2 \rightarrow \_\_\_\_ CO_2 + \_\_\_\_\_ H_20 + \text{energy (ATP + heat)}$$

In complete sentences compare and contrast equations 5 and 6:

Agricultural Chemistry Fertilizer Problems

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Standard of Learning
Math: 6.1, 7.4, 8.3

Objective
The student will:

- Solve percentage problems using the composition of fertilizers

Materials

- AITC Periodic Table to be used as reference
- Calculator
- Student worksheet

Background Knowledge
Students may have seen numbers on the bags of fertilizers used at their homes. Usually the numbers are on the front of the bag and can look like this:
5 – 10 – 10
10 – 10 – 10
5 – 15 – 5 and so on.
The order of these nutrients is always N – P – K. Students can refer to the periodic table to see that these letters represent nitrogen, phosphorus and potassium. From the "Elements of Life" chart on the Ag in the Classroom Periodic Table students can also see that nitrogen is a major requirement for plants and animals and that potassium and phosphorus are also important.

The **percentage problems** included utilize the real world example of fertilizers. The problems in this section can be solved in several ways. Let the students talk this over and try on their own. The following is one way to solve the problems.

Procedure
The following is one way to solve the problems.

1. 50 pound bag of 5-5-5 means that in the 50 pound bag, 5% is nitrogen, 5% is phosphorus, 5% is potassium and 85% (100-5-5-5=85) is filler. 50 pounds x .05 = 2.5 pounds of nitrogen; 50 pounds x .05 = 2.5 pounds of phosphorus; 50 pounds x .05 = 2.5 pounds of potassium; 50 pounds x .85 = 42.5 pounds of filler. This is the size bag that students may be familiar with for home use.

2. One ton of 25-10-10 means that there are 2000 pounds of fertilizer, 25% of which is nitrogen, 10% of which is phosphorus, and 10% of which is potassium. 2000 pounds x .25 = 500 pounds of nitrogen; 2000 pounds x .10 = 200 pounds of phosphorus; 2000 pounds x .10 = 200 pounds of potassium. Filler can be determined by: 2000 – 500 pounds N – 200 pounds P – 200 pounds K = 1100 pounds of filler. Farmers often buy fertilizer in bulk by the ton from the fertilizer dealer. Then a huge spreader truck from the dealer comes on a calm day and spreads the fertilizer on the fields.

3. In the case of 10-10-10, there will be 10% N, 10% P, and 10% K. The total amount bought is 300 pounds, so there are 300 pounds X .1 N = 30 pounds of nitrogen, 300

pounds X .1 P = 30 pounds of P and 300 pounds X .1 K = 30 pounds of K. 10-10-10 is one of the most common fertilizer formulations.

Extension

4. **Why are there different formulas for the fertilizers?** Some answers could include that soil tests were done and found that some nutrients were in the soil and some were lacking or that different crops require different nutrients.
5. **If a farmer is fertilizing an established alfalfa hay field, could the fertilizer used be 5 – 15 – 15 instead of 15-15-15? Support your answer.** Alfalfa is a legume. A characteristic of legumes is that beneficial bacteria live in nodules around their roots. These bacteria fix atmospheric nitrogen into a form which can be utilized by the plants. (see the nitrogen cycle on the Ag in the Classroom Periodic Table). Therefore, a fertilizer with less nitrogen might work.
6. **Why are fillers used in the fertilizers?** It is often difficult to spread a small amount of fertilizer over an entire field. Adding an inert filler allows for more even application and aids the fertilizer in flowing more freely out of the spreader.
7. **A soil test has been done which says that the field needs a fertilizer which supplies 600 pounds/ton of nitrogen, 200 pounds/ton of phosphorus and 300 pounds/ton of potassium. What is the N-P-K label on this fertilizer formula? What percentage of filler is in this fertilizer formula?** Once again, the students may use multiple strategies to figure this out. Remembering that a ton is 2000 pounds and that a percentage is part/whole they can do these three calculations with the N-P-K. 600 pounds N/ 2000 pounds fertilizer = .3 or 30%; 200 pounds P/2000 pounds fertilizer = .1 or 10%; 300 pounds K/2000 pounds fertilizer = .15 or 15% So the formula would be labeled 30 – 10 – 15. The amount of filler in this fertilizer is 2000 pounds – 600 pounds N – 200 pounds P – 300 pounds K = 900 pounds filler. 900 pounds filler/2000 pounds = .45 or 45 % filler.

8. **A farmer decides to use a 40 – 30 – 30 fertilizer on a small 12 acre field. The farm supply store is sending out a truck which will carefully monitor the rate at which it spreads the fertilizer. The fertilizer will be spread at a rate of 400 pounds per acre. How many total pounds of each element, N, P, and K will be put on the field? How much is filler?** This is a multi-step problem which the students can handle in several ways. 400 pounds/acre x 12 acres = 4800 total pounds of fertilizer applied. 4800 x .4 N = 1920 pounds of nitrogen; 4800 x .3 P = 1440 pounds of phosphorus; 4800 x .3 K = 1440 pounds of potassium. A 40-30-30 formulation gives zero pounds of filler.

Agricultural Chemistry Fertilizer Problems

Anhydrous ammonia is the liquid form of pure ammonia gas. It can be added to phosphorus and potassium compounds to make fertilizers. Many granular fertilizers also contain nitrogen, phosphorus and potassium. The amounts of each of these important elements are described on the fertilizer bag as three numbers. For example, a 5 -10 – 10 fertilizer is made up of 5% nitrogen (by weight), 10 % phosphorus, and 10% potassium. The rest of the fertilizer is inert filler. The numbers on the fertilizer bags are always in the same order – nitrogen, phosphorus, and potassium. Sometimes this is referred to as the N-P-K. Look at the Ag in the Classroom Periodic Table “Elements of Life Chart” to see how important these three elements are to plants. When determining the type of fertilizer to apply to a field, a farmer first takes soil samples and conducts a soil test. The lab analyzes the soil and makes recommendations based on the nutrients which are lacking in the soil. Fertilizer costs are going up all the time, so farmers are careful to only apply the amounts which the crops will need.

Directions Using the percentages given, calculate the mass of nitrogen, phosphorus, and potassium as well as the amount of filler in each of the fertilizer formulations below.

1. A 50 pound bag of 5 – 5 – 5 to be applied to a lawn.

2. One ton of 25 – 10 – 10 to be applied to a field of corn.

3. 300 pounds of 10-10-10 to be applied to a garden.

Challenge

4. Why are there different formulas for the fertilizers?

5. If a farmer is fertilizing an established alfalfa hay field, could the fertilizer used be 5 – 15 – 15 instead of 15-15-15? Support your answer.

6. Why are fillers used in the fertilizers?

7. A soil test has been done which says that the field needs a fertilizer which supplies 600 pounds/ton of nitrogen, 200 pounds/ton of phosphorus and 300 pounds/ton of potassium. What is the N-P-K label on this fertilizer formula? What percentage of filler is in this fertilizer formula?

8. A farmer decides to use a 40 – 30 – 30 fertilizer on a small 12 acre field. The farm supply store is sending out a truck which will carefully monitor the rate at which it spreads the fertilizer. The fertilizer will be spread at a rate of 400 pounds per acre. How many total pounds of each element, N, P, and K will be put on the field? How much is filler?

Agricultural Chemistry and Percent Composition of Agricultural Chemicals

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Standard of Learning
Science: PS4, CH3
Math: 6.6, 7.4, 8.3

Objective
The student will:

- Solve percent composition problems involving agricultural compounds
- Practice reading and applying data obtained from the periodic table

Materials
AITC Periodic Table, calculator, student worksheet

Background Knowledge
Calculating Percent Composition

These are percent calculations whereby students are asked the percentages BY WEIGHT of elements within compounds. In order to complete these exercises, students need to be able to utilize the atomic weight from the periodic table. They also need to understand that percentages are calculated by the ratio part/whole or weight of the element/weight of the compound. This is an ideal time to introduce the idea of significant digits or significant figures and rounding. If the weights you use are to 4 sig figs, then the answers to the percent composition problems can also be reported to 4 sig figs. All of the percentages should add up to 100 (or a little more/less due to rounding).

Procedures

1. Calculate the percent composition by weight of hydrogen and oxygen in water, H_2O.

Solution: **WHOLE: WATER: mass of one water molecule**: mass of hydrogen (FROM PERIODIC TABLE) x 2 + mass of oxygen (FROM PERIODIC TABLE) x 1 = (1.008) x 2 + 16.00 x 1 = 18.02 (to four significant digits)
PART: HYDROGEN: Step 1: mass of 1 hydrogen x number of hydrogen atoms in 1 molecule water = 1.008x2 = 2.016 **Step 2**: % composition of hydrogen = part/whole = mass hydrogen/mass of water x 100 = 2.016/18.02 x100.0 = **11.19%** (to four significant digits)
PART: OXYGEN: **Step 1**: mass of 1 oxygen x number of oxygen atoms in1 molecule of water = 16.00 x 1 = 16.00 **Step 2**: % composition of oxygen = part/whole = mass of oxygen/mass of water x 100 = 16.00/18.02 x 100.0 = **88.79%** (to four significant digits)

2. Salt (NaCl) provides livestock with the important nutrients of sodium and chlorine. Calculate the percent composition of sodium and chlorine within salt.

Solution: **WHOLE: SALT (sodium chloride):** mass of one salt molecule: mass of sodium (FROM PERIODIC TABLE) x1 (number of atoms of sodium in one molecule of salt) + mass of one chlorine (FROM PERIODIC TABLE) x 1 (the number of chlorine atoms in one molecule of salt) = (22.99 x 1) + (35.45 x1) = 58.44 (to four sig figs)
PART: SODIUM: Step 1: mass of sodium x number of sodium atoms in one molecule of salt = 22.99 x 1 = 22.99 **Step 2**: % composition of sodium = part/whole x 100 = mass of sodium/mass of sodium chloride x 100 = 22.99/58.44 x 100 = **39.34 %** (to 4 sig figs)

PART: CHLORINE: Step 1: mass of chlorine x number of chlorine atoms in one molecule of sodium chloride = 35.45 x 1 = 35.45 **Step 2:** % composition of chlorine = part/whole x 100 = mass of chlorine/mass of sodium chloride x 100 = 35.45/58.44 x 100 = **60.66%** (to 4 sig figs)

3. **Glucose ($C_6H_{12}O_6$) is the important product of photosynthesis. Calculate the percent composition of carbon, hydrogen, and oxygen within glucose.**

Solution: **WHOLE**: **GLUCOSE (a monosaccarride sugar) :** mass of one glucose molecule: mass of carbon (FROM PERIODIC TABLE) x6 (number of atoms of carbon in one molecule of glucose) + mass of one hydrogen (FROM PERIODIC TABLE) x 12 (the number of hydrogen atoms in one molecule of glucose) + mass of one oxygen (FROM PERIODIC TABLE) x 6 (number of atoms of oxygen in one molecule of glucose = (12.01 x 6) + (1.008 x12) + (16.00 x 6) = 72.06 + 12.096 + 96.00 = 180.2 (to four sig figs)
PART: CARBON: Step 1: mass of carbon x number of carbon atoms in one molecule of glucose = 12.01 x 6 = 72.06 **Step 2**: % composition of carbon = part/whole x 100 = mass of carbon/mass of glucose x 100 = 72.06/180.2 x 100 = **39.99 %** (to 4 sig figs)
PART: HYDROGEN: Step 1: mass of hydrogen x number of hydrogen atoms in one molecule of glucose = 1.008 x 12 = 12.096 **Step 2:** % composition of hydrogen = part/whole x 100 = mass of hydrogen/mass of glucose x 100 = 12.096/180.2 x 100 = **6.713%** (to 4 sig figs)
PART: OXYGEN: Step 1: mass of oxygen x number of oxygen atoms in one molecule of glucose = 16.00 x 6 = 96.00 **Step 2**: % composition of oxygen = part/whole x 100 = mass of oxygen/ mass of glucose x 100 = 96.00/180.2 x 100 = **53.27%** (to 4 sig figs)

4. **Calcium carbonate ($CaCO_3$), lime, is often applied to acid soils to make them more alkaline. Calculate the percent composition of calcium, carbon, and oxygen within lime.**

Solution: **WHOLE: Calcium carbonate (lime) :** mass of one lime molecule: mass of calcium (FROMPERIODIC TABLE) x 1 (number of calcium in one lime molecule) + mass of carbon (FROM PERIODIC TABLE) x 1 (number of atoms of carbon in one molecule of lime) + mass of one oxygen (FROM PERIODIC TABLE) x 3 (number of atoms of oxygen in one molecule of lime = (40.08 x 1) + (12.01 x 1) + (16.00 x 3) = 40.08 + 12.01 + 48.00 = 100.1 (to four sig figs)
PART: CALCIUM: Step 1: mass of calcium x number of calcium atoms in one molecule of lime = 40.08 x1 = 40.08 **Step 2:** % composition of calcium = part/whole x 100 = mass of calcium/mass of lime x 100 = 40.08/100.1 x 100 = **40.04%** (to 4 sig figs)
PART: CARBON: Step 1: mass of carbon x number of carbon atoms in one molecule of lime = 12.01 x 1 = 12.01 **Step 2**: % composition of carbon = part/whole x 100 = mass of carbon/mass of lime x 100 = 12.01/100.1 x 100 = **12.00 %** (to 4 sig figs)
PART: OXYGEN: Step 1: mass of oxygen x number of oxygen atoms in one molecule of lime= 16.00 x 3 = 48.00 **Step 2**: % composition of oxygen = part/whole x 100 = mass of oxygen/ mass of lime x 100 = 48.00/100.1 x 100 = **47.95 %** (to 4 sig figs)

5. **One of the compounds used to provide nitrogen in fertilizer formulations is ammonium sulfate $(NH_4)_2SO_4$. Calculate the percent composition of nitrogen, hydrogen, sulfur, and oxygen within ammonium sulfate. Be careful with this one! There are 2 nitrogen atoms and 8 hydrogen atoms in each molecule of ammonium sulfate.**

Solution: **WHOLE: Ammonium Sulfate :** mass of one $(NH_4)_2SO_4$ molecule: mass of nitrogen (FROM PERIODIC TABLE) x 2 (number of nitrogen in one molecule) + mass of hydrogen (FROM PERIODIC TABLE) x 8 (number of atoms of hydrogen in one molecule) + mass of one sulfur (FROM PERIODIC TABLE) x 1 (number of atoms of sulfur in one molecule) +mass of one oxygen (FROM PERIODIC TABLE) x 4 (number of atoms of oxygen in one molecule of lime = (14.01 x 2) + (1.008 x 8) + (32.06 x 1) +(16.00 x 4) = 28.02 + 8.064 + 32.06 + 64.00 = 132.1 (to 4 sig figs)

PART: NITROGEN: Step 1: mass of nitrogen x number of nitrogen atoms in one molecule = 14.01 x 2 = 28.02 **Step 2:** % composition of nitrogen = part/whole x 100 = mass of nitrogen/mass of molecule x 100 = 28.02/132.1 x 100 = **21.21%** (to 4 sig figs)
PART: HYDROGEN: Step 1: mass of hydrogen x number of hydrogen atoms in one molecule = 1.008 x 8 = 8.064 **Step 2**: % composition of hydrogen = part/whole x 100 = mass of hydrogen/mass of molecule x 100 = 8.064/132.1 x 100 = **6.104 %** (to 4 sig figs)
PART: SULFUR: Step 1: mass of sulfur x number of sulfur atoms in one molecule= 32.06 x 1 = 32.06 **Step 2**: % composition of sulfur = part/whole x 100 = mass of sulfur/ mass of molecule x 100 = 32.06/132.1 x 100 = **24.27 %** (to 4 sig figs)
PART: OXYGEN: Step 1: mass of oxygen x number of oxygen atoms in one molecule= 16.00 x 4 = 64.00 **Step 2**: % composition of oxygen = part/whole x 100 = mass of oxygen/ mass of molecule x 100 = 64.00/132.1 x 100 = **48.45 %** (to 4 sig figs)

Agricultural Chemistry and Percent Composition of Agricultural Chemicals

Calculating Percent Composition

These are percent calculations where you calculate the percentages BY WEIGHT of elements within compounds. In order to complete these exercises, you will need to locate and utilize the atomic weight of each element from the periodic table. Remember that percentages are calculated by the ratio part/whole or weight of the element/weight of the compound. Your teacher will walk you through the first exercise and tell you how many significant digits will be required. All of the percentages should add up to 100 (or a little more/less due to rounding).

1. Calculate the percent composition by weight of hydrogen and oxygen in water, H_2O, which is required for all life.

2. Salt (NaCl) provides livestock with the important nutrients of sodium and chlorine. Calculate the percent composition of sodium and chlorine within salt.

3. Glucose ($C_6H_{12}O_6$) is the important product of photosynthesis. Calculate the percent composition of carbon, hydrogen, and oxygen within glucose.

4. Calcium carbonate ($CaCO_3$), lime, is often applied to acid soils to make them more alkaline. Calculate the percent composition of calcium, carbon, and oxygen within calcium carbonate.

5. One of the compounds used to provide nitrogen in fertilizer formulations is ammonium sulfate $(NH_4)_2SO_4$. Calculate the percent composition of nitrogen, hydrogen, sulfur, and oxygen within ammonium sulfate. Be careful with this one! There are 2 nitrogen atoms and 8 hydrogen atoms in each molecule of ammonium sulfate.

Discovering pH using Chemical Indicators

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Standard of Learning
Science: 6.5, LS4, PS 1, PS 2, Bio 3, CH 3, CH 4

Objective
The student will:

- use the scientific method to conduct a lab
- determine the pH of a variety of foods and household products using three known chemical indicators
- Describe the reaction colors of a homemade vegetable indicator

Materials

- wide range pH paper (pHydrion paper)
- litmus paper
- phenolphthalein solution
- red cabbage juice
- AITC periodic table
- well plates or plastic sheets (like overhead transparencies)
- dropper bottles for phenolphthalein, cabbage juice and substances to be tested
- disposable pipettes
- assortment of food and household items to test which could include vinegar, lemon juice, orange juice, clear soda, tomato juice, milk, water (could be from tap, wells, ponds, lakes, bottles, rain barrel – several local sources), eggs, baking soda (mix this with a little water to make it a solution), household ammonia, soapy water, bleach (CAUTION: AMMONIA AND BLEACH CAN BE VERY HARMFUL – YOU MAY WANT TO TEST THESE SUBSTANCES AS A TEACHER DEMONSTRATION ONLY)

Background Knowledge
pH is the measure of acidity of a substance, technically the concentration of hydrogen ions given as $[H^+]$. In contrast, the pOH is the concentration of hydroxide ions present, given as $[OH^-]$. The relationship of pH to concentration of hydrogen ions is given by: pH = $-\log [H^+]$ (ex: when pH = 3, then [H+] = 1×10^{-3}; 3 = $-\log 1\times10^{-3}$). The pH scale goes from highly acidic (pH of 0), to neutral (ph = 7), to highly basic (ph = 14). pH 0 - pH 6 is acid, pH 7 is neutral, pH 8 – 14 is basic. A solution of a pH of 4 means that there is a concentration of 1×10^{-4} hydrogen ions present (.0001) and a pH of 3 means there is a concentration of 1×10^{-3} hydrogen ions present (.001) and a pH of 2 means there is a concentration of 1×10^{-2} hydrogen ions present (.01). These examples indicate that the scale is exponential, meaning that a substance with a pH of 2 is 10 times more acidic than a substance with a pH of 3 and 100 times more acidic than a substance with a pH of 4.

Biological systems are very sensitive to pH. In streams, a pH of 6.0 to 9.0 is required to insure a healthy ecosystem. Streams beset by acid rain can often fall in the pH range of 3.00 – 5.00, with a resulting loss of fish, plant and insect life. Likewise, the internal pH of animals can effect overall health. Blood and water should have a pH of 7.00, but digestive juices in the digestive system often have a pH of 2.00. The esophagus is harmed when these highly acid digestive juices escape the stomach, as in acid reflux cases.

There are several ways to determine the pH of substances through the use of chemical indicators. An indicator is a compound which responds to a chemical reaction by a specific change in color. In this lab, students will observe the reactions of three known indicators – litmus paper, wide range pH paper, and phenolphthalein. As the students progress through the lab, they will be testing foods and household products with each of these indicators and should ultimately be able to predict how each of these indicators will react to acids and bases. Using the data gathered, they will then be able to describe how home made red cabbage juice can be used as an acid/base indicator. Students can refer to the chart on the back of the Ag in the Classroom Periodic Table to check their results.

Procedure

Prior to lab time, make the red cabbage juice indicator by boiling about half a head of red cabbage in about four cups of water for about 15 minutes. Cool and place in a sealable container (note: The cabbage juice will have an odor and should only be kept for a day or two).

BE SURE TO USE PROPER LABORATORY SAFETY METHODS. CAREFULLY DEMONSTRATE ALL PROCEDURES TO STUDENTS.

1. Each group of students should receive a well plate or sheet of plastic to use for testing. Substances to be sampled should be in individual containers with droppers. Working individually or in groups of two is best.
2. Fill two wells half way full with each substance to be tested or place two drops of each substance to be tested on a plastic sheet. You may want to assign different substances to different groups. However, always have each substance tested by at least two groups in order to verify results.
3. Test each substance with litmus paper and with pH paper.
4. Test one sample of the substance with a drop of phenolphthalein. When dropping the phenolphthalein onto the test sample, be sure TO PREVENT CONTAMINATION BY **NOT TOUCHING THE END OF THE DROPPER TO THE SAMPLE.**
5. Finally, test the other sample of the substance with a few drops of cabbage juice. When dropping the cabbage juice onto the test sample, be sure TO PREVENT CONTAMINATION BY **NOT TOUCHING THE END OF THE DROPPER TO THE SAMPLE.**
6. Students should be able to complete their data chart.

Extensions

- Find two substances on the AITC periodic table pH chart which you did NOT test in the lab. Add these to the data chart and have students PREDICT the proper response to each indicator based on their previous results.
- Test additional foods. These may need to be mashed up a bit or mixed with water to make them easier to test.
- Test the pH of vinegar and the pH of baking soda. Now mix the two carefully, wait for it to fizz and then test the pH. This is an example of neutralization. (NOTE: Vinegar is acetic acid, formula CH_3COOH and baking soda is sodium hydrogen carbonate, formula $NaHCO_3$. When the two combine, the baking soda disassociates to produce a HCO_3^- ion and the vinegar disassociates producing a hydronium ion, H_3O^+. Together they create a neutralization reaction, producing water and CO_2. The net equation looks like this: $HCO_3^- + H_3O^+ \rightarrow 2H_2O + CO_2$. So once the carbon dioxide escapes (the fizz), there should be mostly water left. This would have a pH of 7. However, since this is not a quantitative lab, it is likely that there will not be exact quantities of vinegar and baking soda to completely react so the resulting pH will be somewhere closer to 7 than either vinegar or baking soda, but may not be exactly at 7.)

Safety Concerns

The quantities of all of these materials used is very small, so there is little risk to the students. However, students should be reminded NOT to put any of these compounds in their mouths and that compounds should NOT be sniffed at close range. Of the substances listed, ammonia and bleach are the most toxic and teachers may want to use these for whole class demonstrations. Ammonia has fumes which can be worrisome to both the nose and the eye, so it is suggested that vent fans be turned on or windows opened. Goggles should always be worn when dealing with bleach and ammonia. Goggles should technically be worn when using any glass or chemicals. When working with acids and bases it is always a good idea to have an absorbent available (such as kitty litter) to clean up any spills as well as baking soda on hand to neutralize acid spills and vinegar to neutralize base spills. Lab tables and student hands should be thoroughly washed at the conclusion of this lab.

Discovering pH using Chemical Indicators

Purpose The purpose of this lab is to determine the pH of a variety of foods and house hold products using three known chemical indicators. In addition, a description will be devised describing how red cabbage juice can be used as an acid/base indicator. The pH chart on the Ag in the Classroom Periodic Table can be used for reference.

Background Knowledge The pH scale is a measure of how acid or basic a substance is. Acids have pH values from 0 – 6, neutral is considered a pH = 7, and bases have pH values from 8 – 14. Strongest acids have low pH values and the strongest bases have high pH values. Remember that both very strong acids and very strong bases can be harmful to humans – they can burn your skin! The pH of a substance represents the amount of hydrogen ions present. A low pH, describing acid substances, means a larger amount of hydrogen ions are present.

There are several ways to determine the pH of substances through the use of chemical indicators. An indicator is a compound which responds to a chemical reaction by a specific change in color. In this lab, you will first observe the reactions of three known indicators – litmus paper, wide range pH paper, and phenolphthalein. **Litmus paper** (either pick or blue) responds to acids by turning pink and to bases by turning blue. **Wide range pH paper** responds to each specific pH by turning a specific color. The color the paper turns is matched to a color scale provided and a specific pH can be recorded. **Phenolphthalein** is a clear indicator which stays clear with pH levels below 8, turns pink with pH levels between 8 and 10 and is darker above 10.

Materials

- A place to test samples – well plates or a piece of plastic
- Three known indicators – litmus paper, pH paper, phenolphthalein
- One home made indicator – red cabbage juice
- Eye droppers and containers for indicators and samples
- A variety of food and house hold materials to test

Procedure

1. Follow all safety protocols as described by your teacher.
2. When using the droppers be careful to prevent contamination by **NOT TOUCHING THE END OF THE DROPPERS TO THE SAMPLE.**
3. List the substances to be tested in the left column of your data sheet.
4. Place a drop or two of the sample on the litmus paper. Record the color.
5. Place a drop of two of the sample on the pH paper. Record the color and the pH.
6. Place a drop or two of your sample on the plastic sheet or in the well plate. Then carefully, without contaminating the indicator, place a drop or two of phenolphthalein on the sample. Record the color.
7. Place a drop or two of your sample on the plastic sheet or in the well plate. Then carefully, without contaminating the indicator, place a drop or two of red cabbage juice on the sample. Record the color.

Data chart:

SUBSTANCE	**Color of litmus paper**	**Color of pH paper and pH value**	**Color of phenol-phthalein**	**Color of red cabbage juice**	**Acid or base?**

Questions:

1. The way litmus paper, pH paper and phenolphthalein react to acids and bases were given to you. Describe how red cabbage juice can be used as an indicator. You should list the expected results of strong acids, weak acids, neutral substances, weak bases and strong bases.
2. Which do you think was the best indicator? Why?
3. Why do people with upset stomachs take Milk of Magnesia?
4. Look at the AITC pH chart. Tasting bitter and feeling soapy are characteristic properties of either acids or bases. Which do you think it is? Why? (HINT: which items on the list can be used as cleaning products?)
5. Look at the AITC pH chart. Tasting sour is a characteristic property of either acids or bases. Which do you think it is? Why? (HINT: which of the items on the list sometimes taste sour?)

Agricultural Chemistry: Naming Binary Compounds Using Feed and Fertilizer Tags

Standards of Learning
Science: PS4, CH3

Objective
The student will:

- Use the periodic table to determine the formula and type of bonding of binary compounds
- Determine chemical formulas given compound names
- Write compound names given chemical formulas

Materials
AITC Periodic Table, student naming reference sheet, student worksheet

Background Knowledge
This lesson gives the student practice in naming binary and polyatomic compounds, but also provides the student examples of chemical use in everyday life, through exposure to the ingredient lists in livestock feeds and agricultural fertilizers. Although the primary use of these lessons is naming, there are some extension questions which involve practical math applications and reading within the content area – both very practical skills.

NAMING BINARY AND POLYATOMIC COMPOUNDS – When learning the skill of naming, students usually find it easier to go from the chemical formula to the English, rather than the English to the symbol. Therefore, the first activities in this lesson just require matching the English to the formula symbol. Where students are asked to write the symbols, most of the items are relatively easy and require little balancing.

Creating the correct symbolic formula requires knowledge of and the ability to use oxidation states. Although not terribly difficult, this is not usually a middle school task and is more often found in the high school chemistry curriculum. For ease of use by middle school students, the decision was made not to include oxidation states on the AITC periodic table. However, teachers who would like to pursue this activity more in depth with their students can easily help students to learn the following:

Group 1 elements – the Alkali Metals – Li, Na, K, Rb, Cs, Fr - oxidation number of +1 – They have one electron in their outer shell which is easily pulled off, leaving a charge of +1
REMEMBER THAT ALTHOUGH HYDROGEN IS HERE, IT IS A **NON** METAL.
Group 2 elements – the Alkali Earth Metals – Be, Mg, Ca, Sr, Ba, Ra – oxidation number of +2 – They have two electrons in their outer shell which can be pulled off, leaving a charge of +2
Groups 3 – 12 – the Transition Metals – These metals are characterized by elements which can have more than one oxidation state (Ex: Mn: +2, +3, +4, +7; Fe: +2, +3; Co: +2, +3; Cu: +2, +3)
Group 13 elements– B, Al, Ga, In – oxidation number of +3
Groups 14 -15 elements – Contain metalloids and non-metals with varying oxidation states. The most common ones are C: -4,+2, +4; N: -3, -2, -1, +1, +2, +3, +4, +5; P: -3, +3, +5
Group 16 elements – the Chalcogens – O, S, Se, Te, Po – usual oxidation number is +2
Group 17 elements – the Halogens – F, Cl, Br, I, At – Non metals which only need one electron to fill their outer shell – usual oxidation state is -1.
Group 18 elements– Nobel gases – Ne, Ar, Kr, Xe, Rn – inert gases which have completed outer shells – usual oxidation state is 0

Students can be encouraged to write the correct oxidation number on their Periodic Tables at the top of Groups 1,2,13,16, and 17. They will be able to write formulas for and name many compounds just by learning these few oxidation numbers.

When creating the correct symbol for a binary compound, subscripts are used to balance the oxidation numbers and make a neutral compound. For example – calcium bromide. Calcium has an oxidation number of +2 and bromine has an oxidation number of -1. It will take two bromines to create a charge of -2, which will balance out the +2 of one calcium atom. The result is $CaCl_2$.

Procedure

USING THE NAMING BINARY AND POLYATOMIC COMPOUNDS REFERENCE SHEET - Beginning chemistry students often find a summary sheet with a method for naming compounds helpful. This sheet will give students some structure as they begin learning how to use the periodic table to name compounds. The Type 1 compounds are easy – a metal from the far left and a non-metal from the upper right of the periodic table. Having the students put their left hand on the metals and their right hand on the non-metals is a very physical help. The Type 2 compounds are a transition metal and a non-metal. Students can move their left hand to the center of the periodic table while keeping their right hand on the non-metals in the upper right of the table. (In this reference sheet, Roman numerals are used to indicate oxidation number instead of the older –ous and –ic naming). Type 3 compounds are two non-metals. Students physically move their left hand and place it over their right hand – both of which should now be covering the non-metals in the upper right corner of the periodic table. The reference sheet then gives a REPRESENTATIVE sample of the polyatomics. This is NOT a complete list. Using the periodic table, show the students that the polyatomic series for chlorine (hypochlorite, chlorite, chlorate, perchlorate (which is short for hyperchlorate)) works for the other halogens (fluorine, bromine, iodine) as well. Naming acids and organic compounds are not included in this reference sheet, but can be found in all chemistry books.

KEY FOR WORKSHEETS

FEED: 1. zinc(II)oxide 2. Iron(II)sulfate 3. Manganese(II)oxide 4. Cobalt carbonate 5. Potassium sulfate 6. Calcium iodate 7. Magnesium sulfate 8. Copper (II) sulfate 9. Sodium selenite 10. NaCl 11. $CaCO_3$ 12. $CaCl_2$ 13. CuS 14. KI 15. $FeCO_3$ 16. MgO 17. $MnCO_3$ 18. Na_3PO_4 19. $ZnSO_4$ 20. 12 +2.5+22=36.5%; corn (P,Ft,Fr), barley (P,Ft,Fr), soybean meal (P,F), wheat middlings (P,Fr), soybean hulls (Fr), peanut hulls(Fr) 21. cane molasses 22. minimum and maximum 23. hay or pasture, water, minerals 24. 12% refers to protein percentage 25. ppm = parts per million – used with tiny amounts, a percentage by weight; adding such a small mass to water means about 1 milligram per liter, 1% = 10,000 ppm, so 20 ppm = 0.002%; IU = international units – used for measurement of drugs and vitamins, depends on the potency of the substance, not a unit of mass 26. 1000 x .005 = 5 and 1000 x .015 = 15, so between 5 and 15 pounds of sweet feed per day 27. 1600 x .01 = 16 and 1600 x .015 = 24, so between 16 and 24 pounds of hay per day

FERTILIZER: 1. nitrogen trihydride 2. nitrogen – 2, hydrogen – 4, carbon 1, oxygen 1 3. Ammonium sulfate 4. NH_4NO_3 5. $NaNO_3$ 6. NO_3^{-1} – nitrate 7. potassium and phosphorus 8. NH^{4+} - ammonium and PO_4^{3-} - phosphate 9. $(NH_4)_3PO_4$ 10. diphosporus pentoxide 11. KNO_3 12. potassium carbonate 13. KCl 14. potassium hydroxide 15. K_2O

Agricultural Chemistry Understanding Binary Compound and Fertilizer Tags – Reference Sheet

In ionic compounds, the cation (positively charged metal) is placed before the anion (negatively charged non-metal)

Type 1 – Binary – metal & non-metal – ionic bonding

Name in three parts: __metal__ + ____non-metal root___ + ide

Examples: sodium *chlor*ide (root) Na^{+1} + Cl^{-1} → NaCl

cesium *nitr*ide (root) $3Cs^{+1}$ + N^{-3} → Cs_3N

Type 2 – Binary – transition metal & non-metal – ionic bonding

Name in four parts: transition metal_ + Roman numeral* + non-metal root + ide

* where the Roman numeral represents the charge on the transition metal

Examples:

copper (II) oxide	Cu^{+2} + O^{-2} → CuO
lead (IV) chloride	Pb^{+4} + $4Cl^{-1}$ → $PbCl_4$
iron (III) oxide	$2Fe^{+3}$ + $3O^{-2}$ → Fe_2O_3

Type 3 – Binary – non-metal & non-metal – covalent bonding

Name in five parts: prefix (EXCEPT mono) +1st non-metal + prefix + 2nd nonmetal root + ide

Examples:

boron trifloride	BF_3
dinitrogen pentoxide	N_2O_5

Prefixes to know:

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

Polyatomics – groups of elements which act together like a single element – need to learn the polyatomics and their charges – ionic bonding

Name in three parts: polyatomic or metal + polyatomic or non-metal root + ide

Examples:

sodium sulfite	$2Na^{+1}$ + SO_3^{-2} → Na_2SO_3
manganese(II) hydroxide	Mn^{+2} + $2OH^{-1}$ → $Mn(OH)_2$
ammonium nitrate	NH_4^{+1} + NO_3^{-1} → NH_4NO_3

Some common polyatomics and their charges:

Ammonium NH_4^+	Hypochlorite ClO^-	Carbonate CO_3^{2-}
Nitrate NO_3^-	Chlorite ClO_2^-	Sulfate SO_4^{2-}
Nitrite NO_2^-	Chlorate ClO_3^-	Sulfite SO_3^{2-}
Hydroxide OH^-	Perchlorate ClO_4^-	Phosphate PO_4^{3-}

Agricultural Chemistry Naming Binary Compounds Using Feed and Fertilizer Tags

12% Sweet Feed

A textured feed for mature horses and beef cattle

Guaranteed Analysis

Crude Protein………..(min.)………. 12.00%
Crude Fat ……………(min.)………. 2.50%
Crude Fiber………….(max.)………. 22.00%
Calcium ……(min.)0.9%........(max).. 1.4%
Phosphorus…………..(min.)……….. 0.45%
Salt ………...(min.) 0.5%......(max).. 1.00%
Sodium……. (min.) 0.30%....(max).. 0.80%
Potassium……………(min.)……….. 0.90%
Copper ………………(min.) ………. 20 ppm
Selenium……………..(min.) ……… 0.40 ppm
Zinc…………………. (min.) ……… 3,000 IU/lb.

Ingredients

Cracked Corn, Barley, Dehulled Soybean Meal, Wheat Middlings, Soybean Hulls, Peanut Hulls, Cane Molasses, Ground Limestone, Salt, Potassium sulfate, Magnesium Sulfate, Manganese(II) oxide, Zinc(II) oxide, Iron (II) sulfate, Copper(II) sulfate, Cobalt (II) carbonate, Calcium iodate, Sodium selenite ….. (various vitamin sources)

Feeding Directions

Feed mature horses for maintenance at the rate of 0.5% to 1.5% of bodyweight daily. Feed hay at the rate of 1% to 1.5% of bodyweight daily or provide adequate pasture.
Feed beef cattle at the rate of 1% to 2% of body weight daily. Feed hay at the rate of 1% to 1.5% of bodyweight daily or provide adequate pasture.
Provide clean, fresh water on a continuous basis.
Follow mineral programs recommended for horses and beef cattle.

Using your periodic table and the naming reference sheet, name the listed ingredient which is represented by each of these chemical formulas:

1. ZnO
2. $FeSO_4$
3. MnO
4. $CoCO_3$
5. K_2SO_4
6. $Ca(IO_3)_2$
7. $MgSO_4$
8. $CuSO_4$
9. Na_2SeO_3
10. The chemical name for salt is sodium chloride. Give its chemical formula:
11. The chemical name for limestone is calcium carbonate. Give its chemical formula:

Additional sources of micronutrients in animal feed can come from the following compounds. Using your periodic table and the naming reference chart, write the chemical formula for the following supplemental compounds.

12. Source of calcium – calcium chloride: ____________________

13. Source of copper – copper(II) sulfide: ____________________

14. Source of iodine – potassium iodide: _____________________

15. Source of iron – iron(II) carbonate: ______________________

16. Source of magnesium – magnesium (II) oxide ______________

17. Source of manganese – manganese (II) carbonate ___________

18. Source of phosphorus – sodium phosphate _________________

19. Source of zinc – zinc (II) sulfate _________________________

Additional feed tag questions:

20. The three most abundant components of the feed are protein, fat, and fiber. What is their combined percentage and which ingredients probably provide these?

21. This feed is called "sweet feed". Which ingredient probably provides the "sweet"?

22. What do the terms min and max refer to?

23. Horses and cattle cannot use this sweet feed as their entire food. What else do they need?

24. What does the 12% in the name of the feed refer to?

25. What do the terms ppm and IU stand for?

26. If you have a 1000 pound mare, how much sweet feed should she get per day?

27. If you have a 1600 pound bull, not out on pasture, how much hay should he be fed per day?

Fertilizer Components

The three main elements used in plant fertilizers are nitrogen, phosphorous, and potassium (see Ag Chemistry and Math lesson #1 Fertilizer Problems). The percentages of these appear on bags of fertilizer as three large numbers such as 10 – 10 – 10 or 40 – 20 – 10. In each case, the first number always represents the percent of nitrogen, the second is the percent of phosphorous, and the third is the percent of potassium. This is often referred to as the N- P–K of fertilizer. When these fertilizers are manufactured, many compounds can be utilized as sources of N-P-K.

NITROGEN - Plants are unable to use atmospheric nitrogen (N_2) directly, so the nitrogen either needs to be "fixed" into a usable nitrate form by bacteria living in nodules on the roots of legumes (like alfalfa, beans, peas, clover, soy beans) or produced by chemists and put into fertilizers. Plants need nitrogen for stem and leaf growth. In addition, nitrogen is a component of proteins, hormones, chlorophyll, vitamins, and enzymes – all vital to metabolic functions. Use your periodic table and naming reference sheet as you fill in the blanks for some of these sources of nitrogen:

1. Ammonia is the common name for NH_3. As a type 3 binary compound, what would be it's proper chemical name? ___________________

2. Urea – $(NH_2)_2CO$ – name each element found in this compound and list how many atoms of that element are in one molecule of urea.
   ____

3. $(NH_4)_2SO_4$ – What is the proper chemical name for this polyatomic compound?
   ____

4. Ammonium nitrate – Give the chemical formula __________________

5. Sodium nitrate – Give the chemical formula _____________________

6. Nitric acid – HNO_3 – What is the name of the polyatomic found in this acid?_________________________

PHOSPORUS – The main source of phosphorus is mined rock called rock phosphate. Phosphorous is essential for plant health and growth. It is needed for photosynthesis, protein formation, growth and metabolism. Use the periodic table and naming reference sheets to answer the following about these compounds which provide phosphorus for fertilizers:

7. Monopotassium phosphate – KH_2PO_4 – Which two important fertilizer components are found in this compound? _________________

8. Diammonium phosphate – $(NH_4)_2HPO_4$ – Which two polyatomics are found in this compound? ______________________________

9. Ammonium phosphate – Give the chemical formula ______________

10. P_2O_5 – Name this Type 3 compound __________________________

POTASSIUM – The major source of potassium in fertilizer comes from a mined substance called potash. Potash has many formulas, but all of them contain significant amounts of potassium. Within plants, potassium is important in regulating water absorption and loss and providing a measure of cold hardiness. Potassium is also utilized in protein synthesis and cell division (growth). Give the chemical name or the chemical formula for each of these compounds which might be used to provide the potassium in a fertilizer formulation.

11. Potassium nitrate – Give the chemical formula ________________

12. K_2CO_3 – Give the chemical name __________________________

13. Potassium chloride – Give the chemical formula _________________

14. KOH – Give the chemical name __________________________

15. Potassium oxide – Give the chemical formula __________________

Macromolecules of Life - Carbohydrate Lab

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Standards of Learning
Science: LS1, LS3, LS4, PS2, PS5, Bio1, Bio3

Objective
The student will:
- use the scientific method in conducting an investigation
- learn the response of two chemical indicators to various classes of carbohydrates
- determine the type of carbohydrates which make up a variety of common foods by using two chemical indicators, Benedict's solution and iodine
- determine the carbohydrate type of an unknown and justify his/her conclusion

Materials
- 6 test tubes
- Benedict's solution
- iodine solution,
- droppers or disposable plastic pipettes
- hot water bath
- test tube rack
- well plate
- small beakers with solutions of the following: a known monosaccharide, a known disaccharide, a known polysaccharide, honey, oats, table sugar, apple juice, corn starch, instant potato

Background Knowledge
One of the four main classes of organic compounds found in plants and animals is the carbohydrates. From the "Elements of Life" chart on the Ag in the Classroom Periodic Table, one can see that life forms are 96% carbon, oxygen, hydrogen, and nitrogen. The carbohydrates are made up completely of carbon, hydrogen, and oxygen.

The monomers of the carbohydrates are the simple sugars – a carbon chain (containing three to seven carbons) with a carbonyl group (C=O) attached at varying locations down the carbon chain, usually having some multiple of the formula CH_2O. These are called **monosaccharides** (Greek: monos = one and sacchar = sugar), the most common of which is glucose ($C_6H_{12}O_6$). Glucose is extremely important, in that both plant and animal cells extract the energy stored in glucose molecules during the process of cellular respiration. Other monosaccharides include ribose (a five carbon sugar), galactose and fructose (6 carbon sugars). In solution, these sugars form carbon rings instead of chains.

When two monosaccharides combine, they produce a double sugar polymer called a **disaccharide.** Some common disaccharides include maltose (glucose + glucose), sucrose (table sugar) (glucose + fructose), and lactose (milk sugar) (glucose + galactose). Monosaccharides combine by a condensation reaction, whereby a water molecule is released and a covalent bond is formed, called a glycosidic linkage. Sucrose is important to plants, since this is the form utilized most frequently when carbohydrates are transported from the leaves to the roots.

When many monosaccharides are linked together (a few hundred to a few thousand), polymers called **polysaccharides** are formed. These are considered to be large macromolecules. Animals and plants **use these huge molecules in two ways – as storage molecules** to retain energy reserves and as **structural molecules** to produce strong cellular components.

Storage - Plants store sugars in the form of the polysaccharide **starch**, a helical molecule made of glucose monomers (all of the alpha configuration). When plants (or animals which eat plants), need more fuel for cellular respiration, the large starch polysaccharides are broken apart by hydrolysis (the addition of water). Within the plants, this starch is stored in plastids, one type of which is the chloroplast. Starch can be supplied to animals in the form of foods such as potatoes and grains. Animals store sugars in the form of **glycogen**. This is a polysaccharide made up of glucose molecules organized in a branching pattern. Glycogen is usually stored in the liver and is released when the body needs more energy. The stored glycogen, however, can only supply the needs of animals for about a day. After that, more food is needed.

Structure –Plants combine beta-glucose to form the polysaccharide **cellulose**. In the plant cell walls, cellulose forms long, strong microfibrils. The β- glucose links of cellulose are impossible for animals to digest, therefore herbivores, such as cattle, need the help of micro-organisms in their stomachs to break the cellulose molecules apart. In humans, cellulose cannot be digested – it is the fiber needed to clean out the digestive system. Arthropods such as spiders, insects, and crustaceans use the polysaccharide **chitin** to build their strong exo-skeletons.

There are two chemical indicators that can be easily utilized by students to determine the type of carbohydrate present in foods. First, iodine, when placed on a starch such as bread or potatoes, turns from a rust/red color to dark blue/black. Secondly, Benedict's solution, when heated in the presence of a monosaccharide, turns from a bright, light blue, to an orange/rust color. This heat can be applied either by direct flame, or by heating in a boiling water bath.

Procedure

Both the iodine indicator and the Benedict's solution can be purchased at the correct dilutions from a chemical supply company. The iodine should be stored in dark dropper bottles.

One of the nice aspects of this lab is that it is not quantitatively sensitive – students can use approximate amounts of all materials and get the intended results.

The lab is broken into three parts. First, students will test known samples of monosaccharides, disaccharides and polysaccharides to determine the responses of the indicators. Then they will test a variety of known food stuffs and determine which class of carbohydrates each sample represents. Finally, they will use the two indicator tests to test an unknown sample, determine its composition, and rationalize their conclusion. Using class data is helpful in making conclusions – this represents multiple trials and repeatability and results in class discussion about lab procedures as well as more accurate conclusions.

Lab safety is important. No samples should be tasted. Goggles should be worn when dealing with chemicals, glass test tubes, and the boiling water bath. Remind students that hot glass looks exactly like cold glass!

Students can work individually or in small groups. The easiest way to manage this lab is to have several stations around the room with solutions, samples, indicators and hot plates. Two or three groups of two should be able to work around each station. This lab benefits from the availability of dozens of small beakers or plastic cups so that each station has a supply of all of the stock solutions and sample materials.

This lab takes about 2 hours to set up. The prep is easy, but there are MANY containers involved. Prior to the lab, the teacher should make up solutions (don't worry about quantities – just a spoonful of material in a beaker of water, then stir) to be used as the known mono-, di, and poly – saccharides. Many items can be used, including reagent grade glucose or fructose, sucrose, and starch. Some suggestions for samples for part 2 of the lab include honey, sugar, potato, corn starch, apple juice, and oats. Make solutions of each of these ahead of time. Use instant potato flakes and oatmeal. Mix these with water until they are fairly soupy. Since the potatoes, oatmeal, and corn starch will likely fall to the bottom of the beaker, students should get their samples from the liquid at the top. The unknown can be anything you wish, but hard candies like Jolly Ranchers (slowly dissolve in warm water in a beaker on a hot plate) make colorful unknowns. **Test your unknown ahead of time – candies can either show up as disaccharides due to the sucrose or monosaccharides due to high fructose corn syrup.**

Macromolecules of Life - Carbohydrate Lab

Purpose The purposes of this lab are 1) to learn the response of two chemical indicators to various classes of carbohydrates 2) to determine the type of carbohydrates which make up a variety of common foods by using two chemical indicators, Benedict's solution and iodine and 3) to determine the carbohydrate type of an unknown and justify your conclusion

Background information

Carbohydrates are organic compounds which we commonly call sugars and starches which are made up of carbon, oxygen and hydrogen. The simplest group (or the monomer) of carbohydrates is called the monosaccharides. Disaccharides are polymers composed of two monosaccharides. The most complex group of carbohydrates is the polysaccharides which are polymers composed of three or more monosaccharides. One type of polysaccharide is commonly referred to as starch.

In this experiment we will use two chemical indicators to test for the presence of the different types of carbohydrates from different biological sources. The two indicators in this lab are Benedict's solution and iodine solution. **Benedict's solution**, when heated with a sugar**, indicates the presence of monosaccharides**. **Iodine is a test for polysaccharides**.

You must wear goggles when working with glass, chemicals and heat. Use a test tube clamp – remember that hot glass looks the same as cool glass!

Materials

6 test tubes, Benedict's solution, iodine solution, droppers or disposable plastic pipettes, hot water bath, test tube rack, well plate, solutions of the following: a known monosaccharide, a known disaccharide, a known polysaccharide, honey, oats, table sugar, apple juice, corn starch, instant potato, an unknown solution

Procedure I – Known Saccharides:

1. Label 3 test tubes with pencil: Label #1 **M** for monosaccharides, #2 **D** for Disaccharide and #3 **P** for polysaccharide.
2. To the **M** tube add 30 drops from the stock monosaccharide solution; add the same amount of disaccharide to the **D** tube and polysaccharide to the **P** tube.
3. To each tube add 30 drops of Benedict's solution.
4. Place the three test tubes in the hot water bath until you see a color change (2 – 5 minutes).
5. Record your results and then clean the test tubes well. Erase the labels.
6. Label a well plate with a piece of paper – 3 wells – **M, D, and P**.
7. This time fill each well about HALF FULL from the **M, D**, and **P** stock solutions. Add 3 drops of iodine to each well. DO NOT HEAT.
8. Record results and clean well plate.

Procedure II – Unknown Saccharides:

1. Label six test tubes with pencil: honey, sugar, potato, corn starch, apple juice, oats
2. Complete a Benedict's test on each of the 6 test tubes. (Steps 1 – 5 in Procedure **I**)
3. Using the well plate, label and half fill each well with one of the six known samples. Perform an iodine test on each test tube. (steps 6 – 8 in Procedure **I**)

Procedure III – Unknown Saccharide

1. Using the procedures above, complete a Benedict's solution and an iodine test on the UNKNOWN solution.
2. Record your data below the data chart.

Carbohydrate Lab – Data Table

Procedure I – Known Saccharides

Type of Saccharide	Benedict's Solution Color	Iodine Color
Monosaccharide		
Disaccharide		
Polysaccharide		

Procedure II – Unknown Saccharides

Substance	Benedict's Solution Color	Iodine Color	Predicted Saccharide Type based on your data	Actual Saccharide Type- after seeing and discussing class results
Honey				
Sugar				
Potato				
Corn Starch				
Apple Juice				
Oats				

Procedure III – Unknown

Substance	Benedict's Solution Color	Iodine	Predicted Saccharide Type
UNKNOWN			

Questions – answer in complete sentences:

1. Explain the use of Benedict's Solution as an indicator (what does it look like in the beginning, in what way does it change, what type of saccharide causes the change)
2. Explain the use of an iodine solution as an indicator (what does it look like in the beginning, in what way does it change, what type of saccharide causes the change)
3. What would happen if we placed iodine on paper? Think about what paper is made of as you explain your answer. Try it in lab if you have time.
4. Decide on the type of saccharide which makes up the unknown and tell why you made that decision.

The Nitrogen Cycle- A Closer Look

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Standard of Learning
Science: 6.4, 6.6, LS 7, PS 4, PS 5, ES 12, BIO 9, CH 2

Objective
The student will:

- Use the Nitrogen Cycle graphic on the AITC Periodic Table and information from the teacher to complete a word list pertaining to details about this biogeochemical cycle.
- Trace the chemical changes of nitrogen into multiple compounds as it is transformed at various stages of the nitrogen cycle.

Materials AITC Periodic Table to be used as reference, student worksheet

Background Knowledge

The teacher can use any of this information when discussing the graphic "The Nitrogen Cycle" on the back of the AITC Periodic Table. This can be used with or without the word list which is included as a student worksheet.

A characteristic of all ecosystems is that energy flows through them from the sun to primary consumers, to secondary consumers, etc. with a loss of usable energy at each level. Conversely, matter is always **RECYCLED** (used over and over again) within an ecosystem. With the exception of material added through meteorites and comets, the same amount of matter stays within the Earth and its atmosphere, being cycled between the **BIOTIC** (living), and **ABIOTIC** (non-living) parts of the **ECOSPHERE** (biosphere – living organisms, hydrosphere – water, atmosphere – gases, and geosphere – rocks and minerals). The descriptions of the mechanisms required to cycle matter between living and non-living parts of the ecosphere are called **BIOGEOCHEMICAL** cycles. Among the cycles most commonly cited are the water, carbon, phosphorus and **NITROGEN** cycles. In this lesson, nitrogen is followed from the atmosphere through plants and animals and back into the atmosphere.

Currently the Earth's atmosphere is approximately 78% nitrogen. Therefore, the **RESERVOIR** (largest supply of an element) of nitrogen is considered to be the atmosphere. The form of atmospheric nitrogen is N_2, the **DIATOMIC** form (Diatomic is a compound made of two of the same type of atom. There are seven naturally occurring diatomic elements – H_2, N_2, O_2, F_2, Cl_2, Br_2, and I_2. Students can see that with the exception of hydrogen, the rest of the seven diatomic elements form the shape of a seven with their placement in the periodic table.)

Biologically, nitrogen is an extremely important element for all living organisms, being found in nucleic acids (which make up DNA), amino acids (which make up proteins) and ATP (adenosine tri-phosphate, the energy molecule). However, plants and animals do not have a metabolism which allows them to use nitrogen in the diatomic, atmospheric form – N_2. Therefore nitrogen has to be **FIXED** (chemical form changed) in order to enter food chains and be available for metabolism.

Nitrogen is fixed in three ways. In **ATMOSPHERIC FIXATION**, lightening provides the energy via an electrical discharge which causes a chemical reaction between atmospheric nitrogen and oxygen, forming various oxides of nitrogen (Ex: $N_2 + O_2 \rightarrow 2NO$). **BIOLOGICAL FIXATION** is conducted by two types of nitrogen fixing bacteria. In water and soil, nonsymbiotic cyanobacteria are active. Other important bacteria, called *Rhizobium* live in **NODULES** (swellings) on the roots of **LEGUMES** (plants such as soybeans, clover, alfalfa, beans, peas) in a **MUTUALISTIC SYMBIOTIC** relationship (both species benefit from the relationship). The metabolism of these bacteria converts atmospheric nitrogen into **AMMONIA** ($N_2 + 2H_2 \rightarrow 2NH_3$), which often picks up an additional H+ from acid soils to become the **AMMONIUM ION** (NH_4^+) that can be directly used by plants. Although these bacteria are metabolizing atmospheric nitrogen for themselves, there is enough left over for the plants to absorb and use for their biological functions. Finally, **INDUSTRIAL FIXATION** is when chemical processes such as the Haber Process ($N_2 + 3H_2 \rightarrow 2NH_3$)are used to produce ammonia (sometimes referred to as anhydrous ammonia) which is used as **FERTILIZER** (material used to enrich the soil) and is applied to the soil by humans for use by crops.

The next step in the Nitrogen Cycle is **NITRIFICATION,** the process by which two types of bacteria in the soil change the ammonia into a usable form. First *Nitrosomonas* metabolize the ammonia into nitrites (NO_2) which become nitrite ions (NO_2^-). Then the nitrites are changed by *Nitrobacter* bacteria into nitrates (NO_3^-) or nitrate ions (NO_3^-).
At this point the nitrogen is in forms (nitrate ions, ammonium ions, and ammonia) which are readily assimilated by the plants through their roots. Animals, however, must obtain the nitrogen they need by eating the plants (**HERBIVORES** – primary consumers such as cattle, sheep and goats) or by eating other animals (**CARNIVORES** – secondary consumers such as coyotes and cats) or both (**OMNIVORES** such as pigs and bears).

To get the nitrogen recycled from plants and animals requires the metabolic action of more microbes and decomposers. The nitrogen in dead bodies of plants and animals as well as the nitrogen found in animal wastes (urine contains urea, $CO(NH_2)_2$) is changed in the bacteria by the process of **AMMONIFICATION** into ammonia, NH_3 and water soluble salts containing ammonium ions, NH_4^+. From here, much of the nitrogen stays in the soil and is reused.

However, **DENITRIFICATION** can also take place. In this reaction, additional specialized bacteria can convert ammonia and ammonium ions back into nitrite (NO_2^-) and nitrate (NO_3^-) ions. These are then changed into nitrous oxide gas (N_2O) or nitrogen gas (N_2), both of which return to the atmosphere.

Some nitrogen can be lost to the local ecosystem by **LEACHING** (dissolved and washed away with water) when the soluble nitrate and ammonium ions are dissolved by rain and run off in the ground water. This constant removal of nitrogen is why farmers often apply fertilizers several times in a growing season.

And so goes the Nitrogen Cycle. Although some nitrogen is taken from and then returns to the atmosphere, most nitrogen is recycled locally through decomposition of plant and animal material and then reabsorption by plant roots.

Nitrogen Cycle – A Closer Look

Directions: Define each term as your teacher discusses The Nitrogen Cycle graphic found on the Ag in the Classroom Periodic Table.

Recycled:

Biotic:

Abiotic:

Ecosphere:

Biogeochemical cycle:

Nitrogen Cycle:

Reservoir:

Diatomic:

Nitrogen fixation:

Atmospheric fixation:

Biological fixation:

Nodules:

Legumes:

Mutualistic symbiosis:

Ammonia:

Ammonium ion:

Industrial fixation:

Fertilizer:

Nitrification:

Herbivore:

Carnivore:

Omnivore:

Ammonification:

Denitrification:

Leaching:

Give the chemical formula for the compounds of nitrogen discussed in the description of The Nitrogen Cycle:

Atmospheric nitrogen:

Ammonia:

Ammonium ion:

Nitrite:

Nitrite ion:

Nitrate:

Nitrate ion:

Nitrogen monoxide:

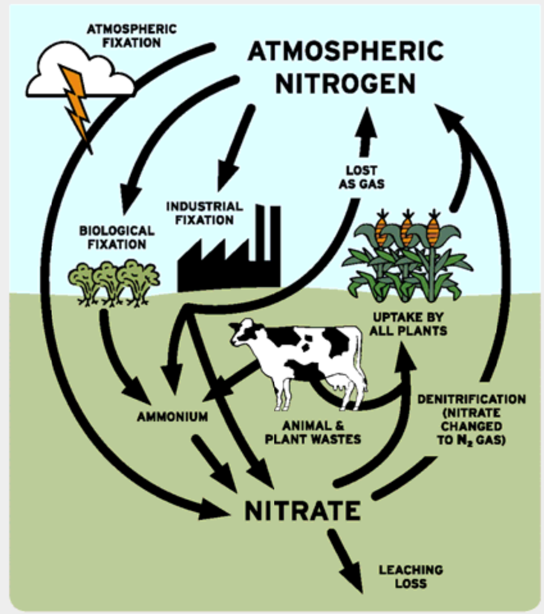
Urea:

Nitrous oxide (dinitrogen monoxide):

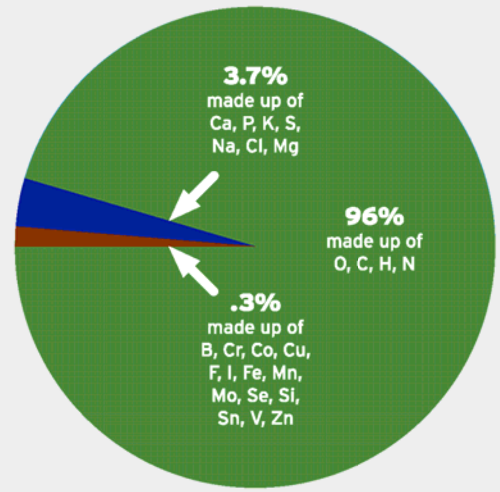
APPROXIMATE pH VALUES

- pH 0 – battery acid
- pH 1 – sulfuric acid
- pH 2 – lemon juice, gastric juices, vinegar
- pH 3 – orange juice, soft drink
- pH 4 – tomato juice, acid rain (Fish die at 4.2)
- pH 5 – rainwater, bananas, (Frog eggs, tadpoles and crayfish die at 5.5)
- pH 6 – healthy lakes, milk (Rainbow trout begin to die at 6.0)
- pH 7 – pure water, human blood
- pH 8 – seawater, eggs
- pH 9 – baking soda
- pH 10 – milk of magnesia
- pH 11 – ammonia
- pH 12 – soapy water
- pH 13 – bleach
- pH 14 – liquid drain cleaner

THE NITROGEN CYCLE



ELEMENTS FOR LIFE



Check out the make-up of all living organisms.

MEASURING CHEMICAL WATER QUALITY

- Dissolved oxygen (DO) — greater than 5.0 mg/l for diverse stream life
- pH — range of 6.0 – 9.0 for living organisms in streams
- nitrates (NO_3^-) less than 10 mg/l for drinking water
- phosphates (PO_4^{3-}) less than .025 mg/l for aquatic life; .015 mg/l for water supply
- temperature — 68°F for cold water streams; 89°F for warm water streams

MEASURING SOIL QUALITY

Soil Test	Acceptable range for lawns/pastures
pH	6.3 to 7.0
Phosphorus (P) lb/acre	50 to 75
Potassium (K) lb/acre	200 to 250
Calcium (Ca) lb/acre	800 to 16,000

- Nitrogen is not usually soil tested because of its change to nitrate and movement through the soil. Plants need a continuous supply of nitrogen, so farmers add nitrogen if needed during the growing season.

DID YOU KNOW?

Nitrogen often is supplied to fertilizer in the form of ammonia or anhydrous ammonia. One way to make ammonia is by the Haber process. Balance the equation showing the Haber process.

$$\_\_\_\_ N_2 + \_\_\_\_ H_2 \rightarrow \_\_\_\_ NH_3$$

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