Landmark Lesson Plan:
Development of Baking Powder

Grades: 9-12
Subject areas: Chemistry and History
Based on “The Development of Baking Powder,” a National Historic Chemical Landmark

The following inquiry-based student activities are designed for use in high school lesson planning. The handout, video and activities will help students understand the chemistry and gain insight into the history featured in the development of baking powder.

The activities are designed as a ready-to-go lesson, easily implemented by a teacher or his/her substitute to supplement a unit of study. In chemistry, the activities relate to nomenclature, formula writing, reactions and organic functional groups. In history, the theme is the interdependence of scientific development and industrialization.

All resources are available online at www.acs.org/landmarks/lessonplans.

While these activities are thematically linked, each is designed to stand alone as an accompaniment for the handout and video. Teachers may choose activities based on curricular needs and time considerations.

- Take a few minutes to introduce the lesson with a few conversation starters. Have any of the students made muffins, biscuits or cakes from scratch? What ingredients did they use? Have they seen baking powder in their kitchens? When do they think people began using baking powder?
- Show the **Video on the Development of Baking Powder**. (6 min.)
- Have students read the handout on the **Development of Baking Powder**.
- Distribute the **Reference Materials** and **Activities** selected for the class.
- After class use the **Answer Guide** for student feedback and discussion.

Student Activities with Objectives

Mapping Activity: Where in the World Did Baking Powder Develop? (20-30 min.)
- Students trace on a map of the world the spread of ideas about chemistry in the 1800s.
- Students contextualize the global nature of the chemical industry by tracing on a map of the world the origin of the basic ingredients in baking powder.

Practice in Chemistry: Get Ready, Get Set, Rise! (30-40 min.)
- Students identify chemical substances relevant to the action of baking powder.
- Students identify substances as ionic or covalent and identify names and formulas of component ions.
- Students write balanced compounds from ion formulas and relate these to baking powder ingredients.
- Students interpret the chemical reaction in baking powder using a chemical equation and use stoichiometry to solve a challenge question.

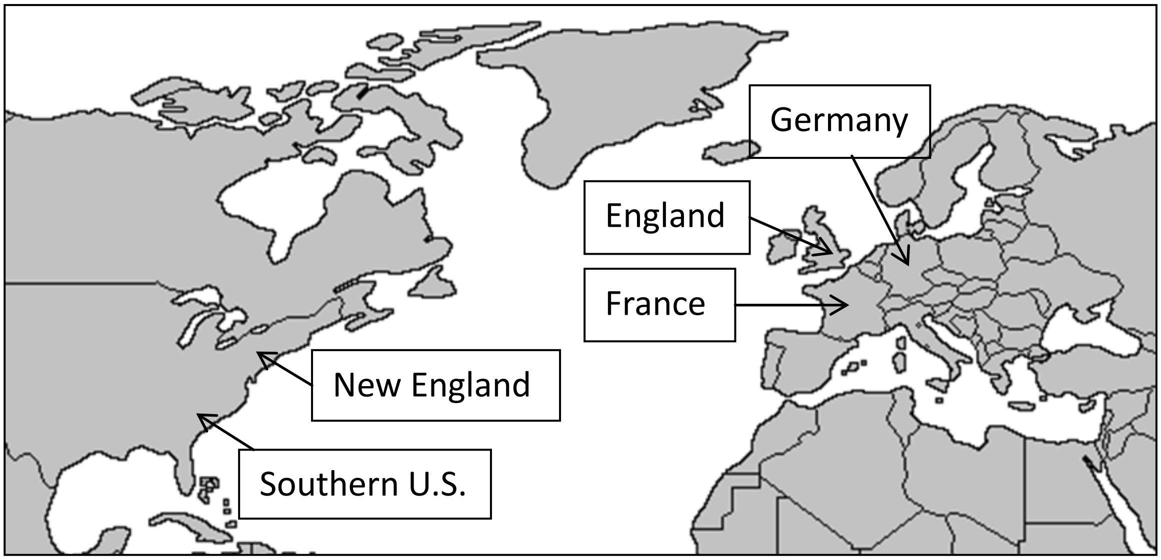
Flow Chart Activity: Why Develop Baking Powder? (15-20 min.)
- Students identify the steps Eben Horsford took to research, invent and market baking powder by completing a flow chart.

Using Venn Diagrams: Comparing Inventions in Food Chemistry (15-20 min.)
- Students compare advances in chemistry using the development of Horsford’s baking powder, Liebig’s beef extract and Ikeda’s monosodium glutamate (MSG).

Exploring Acid Structures: Vinegar, Sour Milk and MSG (10-15 min.)
- Students examine structures of acetic acid, lactic acid and MSG and search for similarities and differences.

Reference Material

Reference Map



Source: http://www.outline-world-map.com/political-outline-world-map-b10a

Names and Charges of Selected Common Ions

Cations		Anions	
Formula	Name	Formula	Name
H^+	Hydrogen	OH^-	Hydroxide
Li^+	Lithium	O^{2-}	Oxide
Na^+	Sodium	O_2^{2-}	Peroxide
K^+	Potassium	$C_2H_3O_2^-$	Acetate
Cs^+	Cesium	$C_3H_5O_3^-$	Lactate
Be^{2+}	Beryllium	$C_4H_5O_6^-$	Bitartrate
Mg^{2+}	Magnesium	$C_5H_8NO_4^-$	Glutamate
Ca^{2+}	Calcium	NO_2^-	Nitrite
Ba^{2+}	Barium	NO_3^-	Nitrate
Al^{3+}	Aluminum	Cl^-	Chloride
Ag^+	Silver	ClO_2^-	Chlorite
Fe^{3+}	Iron (III)	ClO_3^-	Chlorate
Fe^{2+}	Iron (II)	HCO_3^-	Hydrogen Carbonate*
Sn^{4+}	Tin (IV)	CO_3^{2-}	Carbonate
Sn^{2+}	Tin (II)	S^{2-}	Sulfide
Cu^{2+}	Copper (II)	SO_3^{2-}	Sulfite
Cu^+	Copper (I)	SO_4^{2-}	Sulfate
Pb^{4+}	Lead (IV)	HSO_4^-	Hydrogen Sulfate (**)
Pb^{2+}	Lead (II)	PO_3^{3-}	Phosphite
Co^{3+}	Cobalt (III)	PO_4^{3-}	Phosphate
Co^{2+}	Cobalt (II)	HPO_4^{2-}	Hydrogen phosphate
NH_4^+	Ammonium	$H_2PO_4^-$	Dihydrogen phosphate

* also known as bicarbonate ** also known as bisulfate

Selected Molecules

H_2O	Water	H_3PO_4	Phosphoric Acid
CO_2	Carbon Dioxide	$HC_2H_3O_2$	Acetic Acid
NH_4	Ammonia	$HC_5H_8NO_4$	Glutamic Acid
H_2SO_4	Sulfuric Acid	$HC_3H_5O_3$	Lactic Acid

The Development of Baking Powder

The History of Bread

For more than three thousand years, the ingredient used to make bread rise—yeast—did not change substantially. That is, until the 1830s, when bakers began adding sodium bicarbonate (baking soda) and sour milk to their dough. The lactic acid in the sour milk reacts with the baking soda to produce carbon dioxide gas. As the gas is released, it becomes trapped in the dough and produces the desired lightness of the baked bread. This method marked a significant advance for bakers, proving especially useful in the baking of cakes, biscuits and quick breads.

The use of sour milk presented a new problem: It was unreliable, because it was difficult to tell how much acidity the milk contained. The replacement of sour milk with potassium hydrogen tartrate (cream of tartar), a by-product of wine fermentation, solved this problem. Cream of tartar greatly improved the baking process because the reaction was now much more predictable.

The mixing of baking soda and cream of tartar marked the introduction of baking powder. But the two chemicals had to be kept in separate containers until used, or else they would react if any moisture was present. And because cream of tartar was imported from France, there were the additional problems of supply and expense. These factors fueled the search for a more efficient and economical baking powder.

Eben Horsford

Eben Horsford

Eben Horsford was the American-born scientist who solved this problem by replacing cream of tartar with calcium acid phosphate, also known as monocalcium phosphate.

Horsford had studied chemistry in Germany with Justus von Liebig, a prominent agricultural chemist, in 1844. He returned to the United States to become a professor of science at Harvard University in Cambridge, Massachusetts.

Although chemists at the time were familiar with calcium acid phosphate, it had not been made previously on a commercial scale. Horsford developed a process to manufacture the ingredient using cattle bones, which were ground and digested with sulfuric acid. The result was a mixture of phosphoric acid, superphosphates and calcium sulfate, which could then processed to produce calcium acid phosphate.

Horsford and his business partner, George Wilson, opened the Rumford Chemical Works in Rhode Island in 1854. Five years later, they began manufacturing and selling the correctly proportioned ingredients. They named their company after Count Rumford, the inventor who endowed Horsford's position at Harvard.

While the introduction of calcium acid phosphate solved the problems of using cream of tartar, the baker still had to mix two products to get a satisfactory reaction. Horsford solved this final problem by thoroughly drying the ingredients and adding corn starch to keep them dry. In 1869, the Rumford plant began manufacturing baking powder as we know it today.

Since then, the only significant change has been source of the calcium acid phosphate. In the late 1880s, calcium phosphate mining eliminated the need for beef bones.

Count Rumford

Benjamin Thompson was born in Woburn, Massachusetts, in 1753. As a young man, he was a supporter of Britain during the years leading up to the American Revolution. When British forces evacuated Boston in March 1776, Thompson followed and sailed to England. There Thompson served under Lord Germain, Britain's Secretary of State for America.

When Britain was defeated by the American colonies, Germany was accused of incompetence. To avoid the problems of his association with Germany, Thompson left for travel on the European continent.

After several months of travel, Thompson entered the service of Karl Theodore, the Elector of Bavaria, in today's southern Germany. The Elector made Thompson a Count of the Holy Roman Empire. Thompson was allowed to choose his own title, and he selected Rumford, the early name of Concord, New Hampshire, where he had taught school and where his first wife had been born.

Throughout his wanderings in Europe, Rumford conducted scientific research on a variety of topics, including gunpowder, light and mechanics. His major focus was on heat, which he believed was a form of motion.

Rumford spent the last dozen years of his life in Paris. When he died in 1814, he left Harvard University money to establish a professorship in his name "to teach…the utility of the physical and mathematical sciences…for the extension of industry, prosperity, happiness, and well-being of Society."

Justus von Liebig

As a child, Justus von Liebig was curious about chemistry, having been exposed to it through his family's business in painting and common chemical supplies.

After studying chemistry in Germany and France, von Liebig began teaching at the University of Giessen, Germany, in 1824. There, von Liebig became a renowned chemistry instructor and created one of the world's first major teaching laboratories for chemistry. Students from America and throughout Europe traveled to Giessen to study under his direction.

Von Liebig was especially interested in agricultural chemistry—the study of methods for growing food and producing useful products from agricultural sources. He discovered that plants feed on nitrogen from the soil and introduced nitrogen-based fertilizer. Fertilizers are used around the world today to increase yields of crops.

Another of von Liebig's inventions was beef extract, a highly concentrated beef stock that was a nutritious substitute for more expensive beef. Von Liebig started a company that produced beef extract in Uruguay and began selling it in European markets. Von Liebig's beef extract was popular in European households, and provided nutrition to soldiers during World War II.

Von Liebig is remembered for both his influential teaching and for his discoveries. The ideas proposed in his classroom provided the basis for research that continued for many years following his death in 1873.

Kikunae Ikeda

For many of years, people recognized four main tastes: sour, sweet, salty and bitter. Only recently were Americans introduced to a fifth taste: Umami.

Umami was discovered by Kikunae Ikeda, a Japanese chemistry professor at Imperial University of Tokyo, in 1908. Ikeda had studied chemistry in Germany with Wilhelm Ostwald in 1899.

Ikeda recognized that the flavor of broth made from kombo, a popular type of seaweed used in cooking, exhibited a flavor distinct from the four tastes recognized at the time. In laboratory tests using seaweed, he isolated the substance I-glutamate, known today as monosodium glutamate, or MSG. Ikeda acquired a patent for manufacturing MSG in 1908. Soon after, Ikeda worked with Saborusuke Suzuki, a businessman, to manufacture and market MSG as a flavor enhancer under the Ajinomoto brand name.

Although it is associated with Asian foods and restaurants, MSG is used in home kitchens and industrial food processing factories around the world to enhance flavor in a variety of foods, including broths, seasonings, potato chips and other snacks.

Since Ikeda's discovery, other foods have been recognized for their umami flavor. Tomatoes, cheeses, meats and mushrooms, for example, all exhibit the flavor of umami. And other flavor compounds, notably fattiness and piquience (spicy heat) have been proposed.

Student Name: ____ Date: _______________ Period: ______

Mapping Activity: Where in the World Did Baking Powder Develop?

Map #1 Trace the spread of ideas about chemistry in the 1800s.

Directions:

Use the information from the video and the article on baking powder to record the movement of the three chemists. There is a political map on your reference sheet to help you identify where the countries are located.

1. Write “Justus von Liebig” in Germany, where he lived, and France, where he studied.
2. Write “Count Rumford” in New England, England, Germany and France where he traveled and lived. Draw lines with arrows to show the direction of his journeys.
3. Write “Eben Horsford” in New England and Germany. Draw lines with arrows to show the direction of his journeys.

Student Name: ____ Date: _______________ Period: ______

Mapping Activity: Where in the World Did Baking Powder Develop?

Map #2 Trace the origin of ingredients used in baking powder

Directions:

Identify the origin of the basic ingredients in baking powder from its two stages of development in the USA by following the steps below:

1. Write “baking soda” in France because that’s where it was invented and manufactured.
2. Write “sour milk” in New England because that’s where the cows American bakers used for milk came from.
3. Write “cream of tartar” in France because it was a by-product of the wine fermentation process there.
4. Write “calcium acid phosphate” in New England because that’s where the beef bones the Rumford Chemical Works used came from.
5. Write “corn starch” in New England because that’s where corn (maize) was grown in the 1800s.
6. Write “calcium phosphate” in the Southern U.S. because that’s where the phosphate mines were in the 1800s.

Student Name: ____ Date: _______________ Period: ______

Practice in Chemistry: Get Ready, Get Set, Rise!

The chemical compounds and reactions that play a role in baking powder chemistry are the same substances you see reacting in many natural processes—how we breathe, how plants grow, how caves form underground, how sea creatures make their shells. In this exercise you will name them, write their formulas and see how their reactions can make biscuits rise!

Practice #1: Get Ready

List the names of ten different chemical substances referred to in the first page of the article. For example, the first substance referred to in paragraph one is "sodium bicarbonate."

Chemical substances are of two types, **ionic** and **covalent**. Ionic compounds are composed of **ions** (positive or negatively charged particles), and covalent compounds are composed of **molecules**.

Using the chart, "Names and Charges of Selected Common Ions," name each of the **ions** below. We will use some of these to name the substances found in baking powder:

Na^{+}		K^{+}	
Ca^{2+}		CO_3^{2-}	
HCO_3^{-}		SO_4^{2-}	
PO_4^{3-}		$H_2PO_4^{-}$	
HPO_4^{2-}		$C_4H_5O_6^{-}$	

Now, using your reference page, name each of these **molecules**:

H_2O		CO_2	
H_2SO_4		H_3PO_4	
$HC_3H_5O_3$		$HC_5H_8NO_4$	

Practice #2: Get Set

The ions in ionic compounds combine in a ratio that makes the overall charge of the substance add up to zero. For example, sodium carbonate is a substance composed of two sodium (Na^+) ions and one carbonate (CO_3^{2-}) ion. (Two plus one charges and one two minus charge add up to zero). The **formula** for sodium carbonate is written Na_2CO_3. Note that the formula for the substance does not show the charges on the ions, and the name of the substance is just the name of the positive and negative ions together.

Remember: if you need more than anion, enclose it in parentheses like this: $Ca(HCO_3)_2$

Write the formulas and names for the substances that would be formed from:

Positive ion	**Negative ion**	**Formula**	**Name**
Na^+	CO_3^{2-}	Na_2CO_3	sodium carbonate
Na^+	HCO_3^-	*	
Ca^{2+}	CO_3^{2-}		
Ca^{2+}	SO_4^{2-}		
Ca^{2+}	PO_4^{3-}		
Ca^{2+}	HPO_4^{2-}		
Na^+	HPO_4^{2-}		
Ca^{2+}	$H_2PO_4^-$	**	
K^+	$C_4H_5O_6^-$	***	

* Also known as baking soda
** Also known as "calcium acid phosphate," Horsford's secret ingredient!
*** Also known as cream of tartar

Now go back to "Get Ready" and look at the first list you made of chemical substances you found in the article. Find at least six compounds in your list whose formulas you now know, and write the names and formulas of those six below.

Name	**Formula**

Name	**Formula**

Practice #3: Rise!

Let's put all of this together to understand how Horsford put bubbles into batter!

There is one more thing to understand before we look at how these substances react.

When an acid (a covalent compound that gives up H+ ions when dissolved in water) is added to a compound with carbonate or bicarbonate, the molecule H2CO3 is formed, and when enough of this forms in water, it rearranges itself to become H2O and CO2. We write the reaction like this:

$$H^+ + HCO_3^- \rightarrow H_2CO_3$$

$$H_2CO_3 \rightarrow H_2O + CO_2$$

Carbon dioxide, as we know, is a gas, so the reaction releases bubbles into batter. Now, name the reactants and products in the reaction that takes place to form CO_2 from the ingredients in Horsford's baking powder:

$$2\ NaHCO_3 + Ca(H_2PO_4)_2 \rightarrow Na_2HPO_4 + CaHPO_4 + 2\ H_2O + 2\ CO_2$$

Fill in the blanks using chemical names to describe the baking powder reaction:

____________________ and ____________________ are the two main ingredients in baking powder, and they react when moistened to form ____________________, ____________________, ____________________ and ____________________.

Expand! (A challenge problem using stoichiometry)

When baking powder is packaged, the sodium bicarbonate and calcium acid phosphate must be mixed in the correct ratio. Using the balanced equation above and a periodic table, find the mass of calcium acid phosphate needed to react completely with 500.0 g of sodium bicarbonate.

Answer: ____________________

Student Name: ____ Date: _______________ Period: ______

Flow Chart Activity: Why Develop Baking Powder?

Before baking powder, there were mainly two ways used to make biscuits or bread light and fluffy. The first way was to add small air bubbles into the dough by beating it with a spoon or a whisk, like you would whip up whipped cream. This was difficult work! The second way, which is still used for most breads, is to add yeast. Yeast are microorganisms that digest sugars and produce carbon dioxide, which then forms bubbles in the dough. In this case, the yeast did the work, but it took hours for the dough to rise. The development of baking powder introduced a third path to leavening dough.

Directions:

Use the video, the article on the history of baking powder, and the flowchart below to answer the following questions.

1830s: Why did American bakers switch from yeast to a combination of sodium bicarbonate and sour milk?

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1840s: Why did American chemists switch from sour milk to cream of tartar?

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1850s: Why did Eben Horsford want to help bakers switch from cream of tartar to calcium acid phosphate?

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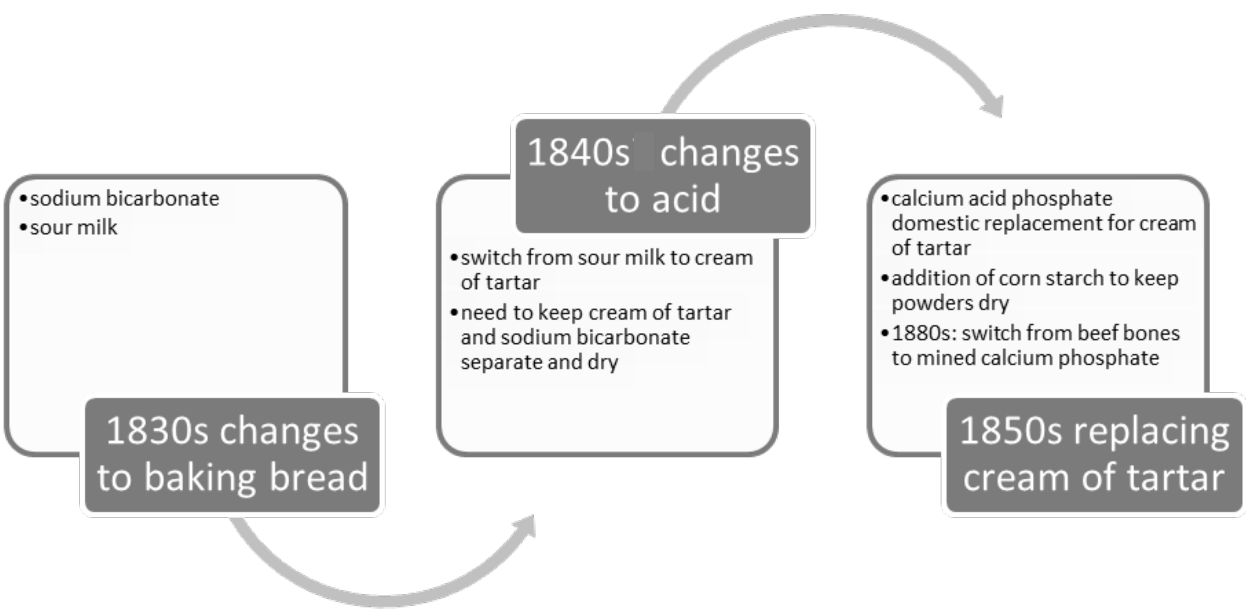
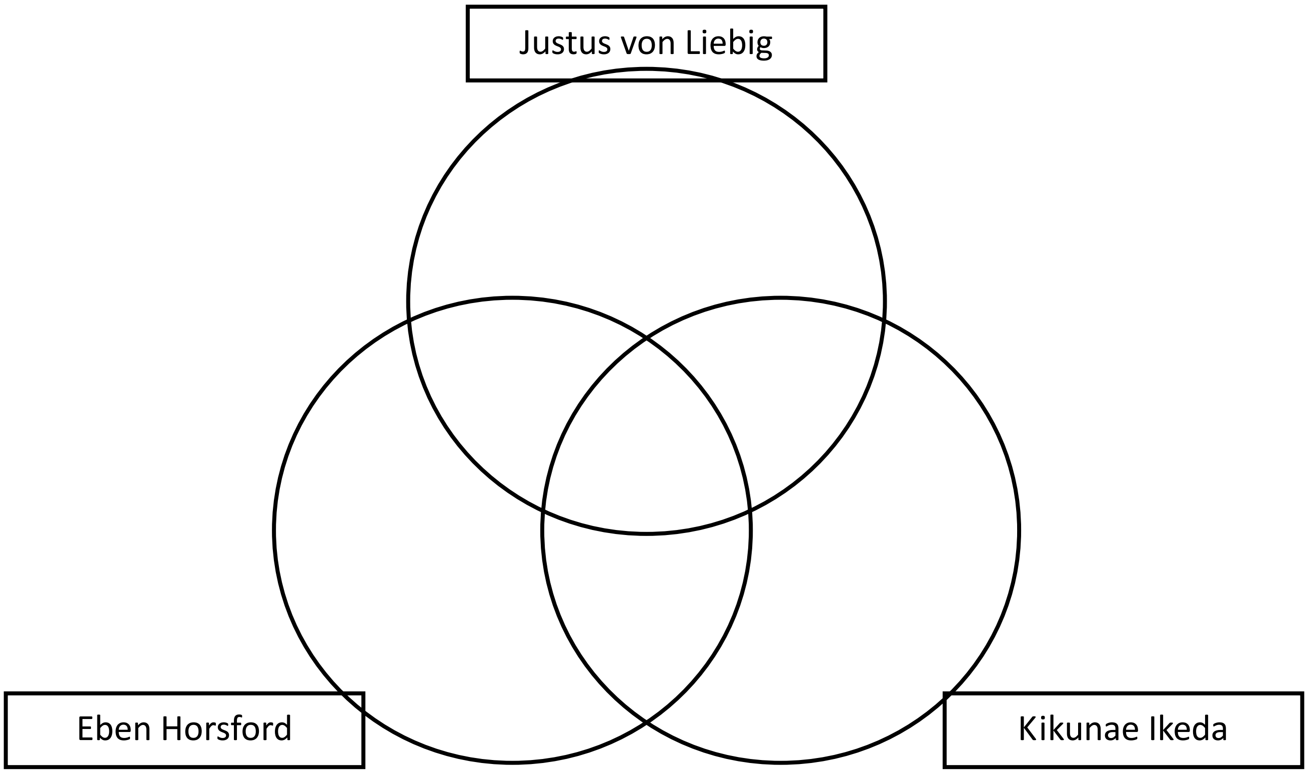


Student Name: ____ Date: _______________ Period: ______

Using Venn Diagrams: Comparing Inventions in Food Chemistry

With each circle representing one of the chemical inventors, place facts from the information below in an appropriate section of the triple Venn Diagram to compare the development of Liebig's beef extract, Horsford's baking powder and Ikeda's MSG.



Justus von Liebig, a German agricultural chemist, studied in Germany and France and started an academic laboratory for teaching chemistry.

1824	Began teaching at the University of Giessen, in Germany.
1840	Invented beef extract, a nutritious substitute for expensive beef.
1865	Started a company in Uruguay to produce beef extract for European markets.
1940's	Liebig's beef extract is used to feed Allied armies during World War II.

Eben Horsford, an American chemist, was the scientist who developed and manufactured the first baking powder in a single container.

1844	Studied chemistry at the University of Giessen with Liebig.
1854	Started the Rumford Chemical Works with George Wilson in Rhode Island.
1859	Introduces calcium acid phosphate as a substitute for cream of tartar in baking powder.
1869	Improves baking powder with the addition of corn starch to keep the ingredients dry.

Kikunae Ikeda, a Tokyo Imperial University professor of chemistry, discovered monosodium glutamate (MSG) and the flavor umami.

1899	Studied chemistry with William Ostwald at Leipzig University in Germany.
1908	Isolated MSG from seaweed and developed a process for manufacturing MSG.
1908	Started the Ajinomoto Corporation to manufacture and market MSG as a food product.

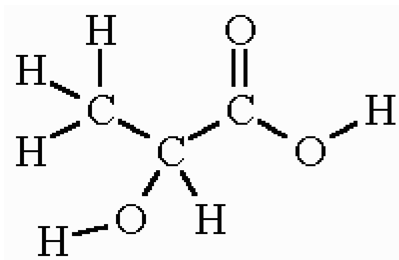
Student Name: ____ Date: _______________ Period: ______

Exploring Acid Structures: Vinegar, Sour Milk and MSG

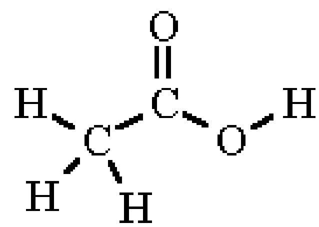
What do MSG, vinegar and lactic acid (found in sour milk) all have in common? The structural formulas of the three substances drawn below show how the atoms within the molecules bond with one another.

<u>Directions:</u>

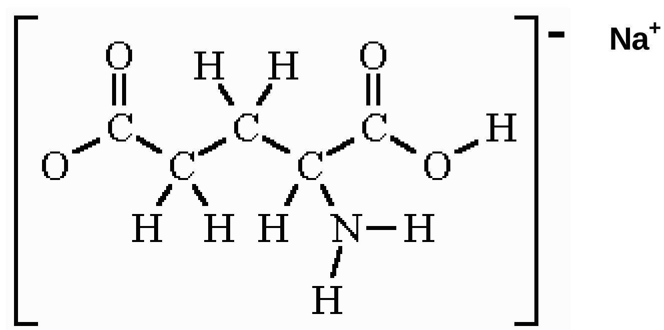
Examine the molecular structures, count the atoms and write the chemical formula for each substance next to it. For example, the chemical formula for acetic acid is $C_2H_4O_2$.



Lactic Acid (in milk)



Acetic Acid (in vinegar)



Monosodium glutamate (MSG)

Now circle the parts of each of these structures that the three substances have in common.

Specifically describe how the structures are similar.

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How are they different?

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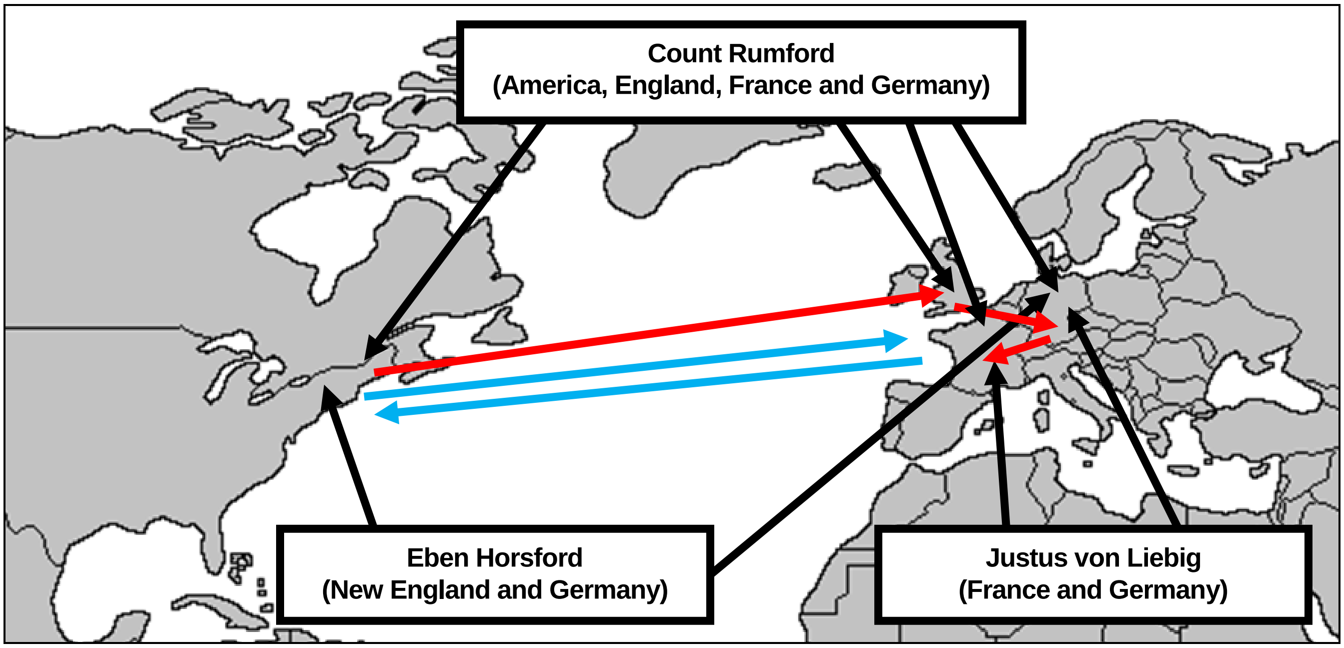
Development of Baking Powder Answer Guide
Mapping Activity: Where in the World Did Baking Powder Develop?

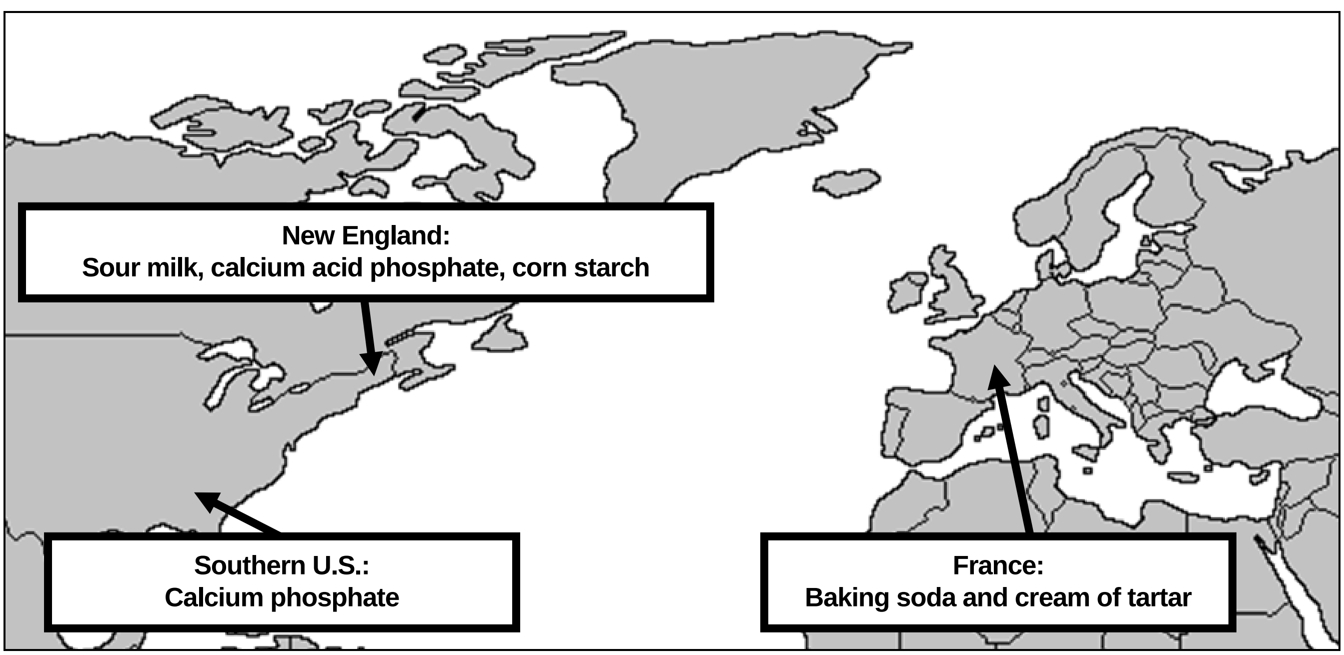
Map #1: Trace the spread of ideas about chemistry in the 1800s.



Red arrows indicate Count Rumford's travels. Starting in New England, Rumford traveled to England, then Germany, and finally France.

Blue arrows indicate Eben Horsford's travels. Starting in America, Horsford traveled to Germany for school, then returned to the U.S.

Map #2 Trace the origin of ingredients used in baking powder.



Development of Baking Powder Answer Guide
Practice in Chemistry: Get Ready, Get Set, Rise!

Practice #1: Get Ready

List the names of ten different chemical substances referred to in the first page of the article.

Sodium bicarbonate (baking soda)	**Lactic acid**
Carbon dioxide	**Potassium hydrogen tartrate (cream of tartar)**
Water	**Calcium acid phosphate or monocalcium phosphate**
Sulfuric acid	**Phosphoric acid**
Superphosphates	**Calcium sulfate**

Using the chart, "Names and Charges of Selected Common Ions," name each of the ions below. We will use some of these to name the substances found in baking powder.

Na^{+}	**sodium ion**
Ca^{2+}	**calcium ion**
HCO_3^{-}	**bicarbonate or hydrogen carbonate**
PO_4^{3-}	**phosphate**
HPO_4^{2-}	**hydrogen phosphate**

K^{+}	**potassium ion**
CO_3^{2-}	**carbonate**
SO_4^{2-}	**sulfate**
$H_2PO_4^{-}$	**dihydrogen phosphate**
$C_4H_5O_6^{-}$	**bitartrate or hydrogen tartrate**

Now, using your reference page, name each of these molecules.

H_2O	**water**
H_2SO_4	**sulfuric acid**
$HC_3H_5O_3$	**lactic acid**

CO_2	**carbon dioxide**
H_3PO_4	**phosphoric acid**
$HC_5H_8NO_4$	**glutamic acid**

Development of Baking Powder Answer Guide
Practice in Chemistry: Get Ready, Get Set, Rise! (continued)

Practice #2: Get Set

Write the formulas and names for the substances that would be formed from:

Positive ion	Negative ion	Formula	Name
Na^+	CO_3^{2-}	Na_2CO_3	sodium carbonate
Na^+	HCO_3^-	*** $NaHCO_3$**	**sodium bicarbonate**
Ca^{2+}	CO_3^{2-}	**$CaCO_3$**	**calcium carbonate**
Ca^{2+}	SO_4^{2-}	**$CaSO_4$**	**calcium sulfate**
Ca^{2+}	PO_4^{3-}	**$Ca_3(PO_4)_2$**	**calcium phosphate**
Ca^{2+}	HPO_4^{2-}	**$CaHPO_4$**	**calcium hydrogen phosphate**
Na^+	HPO_4^{2-}	**Na_2HPO_4**	**sodium hydrogen phosphate**
Ca^{2+}	$H_2PO_4^-$	*** $Ca(H_2PO_4)_2$**	**calcium dihydrogen phosphate**
K^+	$C_4H_5O_6^-$	*** $KC_4H_5O_6$**	**potassium hydrogen tartrate**

Find at least six compounds in your list whose formulas you now know and write the names and formulas of those six below. (Any six of these.)

Name	Formula
sodium bicarbonate	**$NaHCO_3$**
lactic acid	**$HC_3H_5O_3$**
carbon dioxide	**CO_2**
cream of tartar	**$KC_4H_5O_6$**
calcium acid phosphate	**$Ca(H_2PO_4)_2$**

Name	Formula
sulfuric acid	**H_2SO_4**
phosphoric acid	**H_3PO_4**
calcium sulfate	**$CaSO_4$**
calcium phosphate	**$Ca_3(PO_4)_2$**

Practice #3: Rise!

Fill in the blanks using chemical names to describe the baking powder reaction:

Sodium bicarbonate and **calcium acid phosphate** (also known as calcium dihydrogen phosphate) are the two main ingredients in baking powder, and they react when moistened to form **sodium hydrogen phosphate**, **calcium hydrogen phosphate**, **water** and **carbon dioxide**.

Expand! (A challenge problem using stoichiometry)

500.0 g $NaHCO_3$ x 1 mol $NaHCO_3$ / [22.99 g + 1.01 g + 12.01 g + 3(16.00 g)] = 5.95 mol $NaHCO_3$

5.95 mol $NaHCO_3$ x 1 mol $Ca(H_2PO_4)_2$/ 2 mol $NaHCO_3$ = 2.98 mol $Ca(H_2PO_4)_2$ required to react with the sodium bicarbonate

2.98 mol $Ca(H_2PO_4)_2$ x (40.08 g + 2[2(1.01 g) + 30.97 g + 4(16.00 g)]) /1 mol $Ca(H_2PO_4)_2$ = 697.50 g $Ca(H_2PO_4)_2$

Development of Baking Powder Answer Guide
Flow Chart Activity: Why Develop Baking Powder?

Use the video, the article on the history of baking powder, and the flowchart to answer the following questions.

1830s: Why did American bakers switch from yeast to a combination of sodium bicarbonate and sour milk?

> **Using sodium bicarbonate plus acidic cream of tartar produced carbon dioxide bubbles more quickly than waiting for the yeast to grow in the dough.**

1840s: Why did American chemists switch from sour milk to cream of tartar?

> **Using a measured amount of cream of tartar gave more reliable results than using sour milk. Cream of tartar was also a dry ingredient and could be stored with the sodium bicarbonate for use when it was convenient to the baker.**

1850s: Why did Eben Horsford want to help bakers switch from cream of tartar to calcium acid phosphate?

> **Since calcium acid phosphate was manufactured using beef bones, and later, phosphate minerals, it was easier for Horsford to obtain than cream of tartar, which was obtained from France as a byproduct of wine fermentation.**

Development of Baking Powder Answer Guide
Using Venn Diagrams: Comparing Inventions in Food Chemistry

<u>Note to teacher</u>: This activity is not necessarily meant to have one set of "right answers," or even to have a piece of information in every space. It's a way to help students process information - to relate what they have learned about baking powder to a larger picture of the business of chemistry.

Each of the inventors of this era studied chemistry in Germany, responded to the need for a product, developed the product, found the resources to produce it and formed chemical companies that eventually had a global impact.

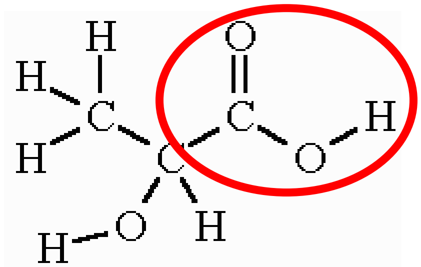
Some students will pick up on some aspects and include them in their diagrams, and others will pick up on more. In that respect it is a good exercise in differentiation and student responses could be the basis for group or class discussion at a later time if the teacher chooses to pursue it.

Development of Baking Powder Answer Guide
Exploring Acid Structures: Vinegar, Sour Milk and MSG

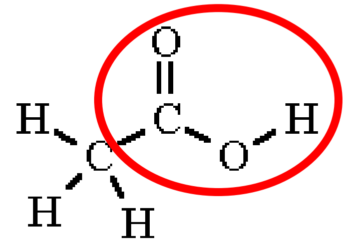
Chemical formulas for the three substances:

Lactic Acid	**$C_3H_6O_3$**
Acetic Acid	**$C_2H_4O_2$**
Monosodium glutamate	**$NaC_5H_8NO_4$**

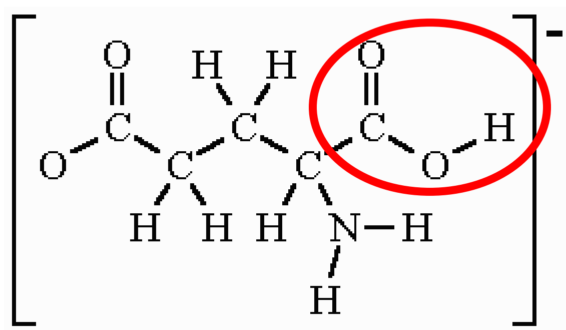
Now circle the parts of each of these structures that the three substances have in common.



Lactic Acid (in milk)



Acetic Acid (in vinegar)



Na^+

Monosodium glutamate (MSG)

Specifically describe how the structures are similar.

Each substance is structurally based on a carbon chain of single bonds; each substance contains the acidic carboxyl functional group, -COOH and therefore has acidic properties.

How are they different?

Lactic acid has a longer carbon chain than acetic acid, and MSG has the longest carbon chain with 5 carbons. Acetic acid has one functional group, the carboxyl group, lactic acid has a carboxyl group and an OH (hydroxyl) group, and glutamate has carboxyl as well as an amine group (- NH_2) . Acetic and lactic acids are covalent molecules while MSG is an ionic compound or salt comprised of a sodium metal cation and the polyatomic glutamate anion.