UNIT 3

TEACHING THIS INVESTIGATION

Framing problem/ question	**How can looking at the same information from different perspectives pave the way for progress?**	
Why do historians, scientists, and others care about this question?	Changes in thinking and ideas are often central to igniting historical change. A wonderful case study of the role ideas can play in driving innovation is the story of the change in our understanding of the material world and its elements. Lavoisier, the "father of modern chemistry," altered the way people had viewed the elements, changing a point of view that had been dominant since Aristotle's time. His redefinition of the chemical elements and their properties enabled dramatic discoveries. These in turn led to new understanding of the elements and their relationship to one another, enabling a new scheme of organizations — the periodic table — and field of chemistry we know today.	
Why should teachers and students of big history care about this question?	Students do not always see ideas as powerful forces for change. This investigation encourages them to consider how a new point of view can pave the way for new discoveries and create progress. The investigation asks students to look at chronological and causal relationships among ideas, such as Lavoisier's view of elements and Mendeleev's periodic table, and discoveries of new elements and new uses for those elements. Extending their understanding of the content in Unit 3, students should also further develop their skills in considering source and context, while corroborating information located in different documents. We have provided a table for students to analyze the text, gather facts, and connect the texts to the question "How can looking at the same information from different perspectives pave the way for progress?"	
What texts are in the Investigation Library?	Primary Sources	• Lavoisier's list of chemical elements • The periodic table (1871)
	Secondary Sources	• Aristotle's elements • Lavoisier, "father of modern chemistry" • Timeline of discovery of elements • Importance of the periodic table • Elements, baseball bats, and bike frames
What is the students' project or prewriting task?	**Considering causal relationships:** Have students fill one or more of the graphic organizers provided to show their understanding of how Lavoisier's and other's points of view paved the way to other new ideas and discoveries.	
What is the students' writing task?	**Create an explanation:** Have students use their graphic organizer, reading table, notes, and documents in the Investigation Library to write an explanation of why and how new ideas drive new discoveries and progress. In a four- to five-paragraph essay, students should use the story of the change in understanding of the elements and their organization to explain how new points of view pave the way for new discoveries and progress. Students should be able to connect this case to other big history concepts, such as collective learning or thresholds of increasing complexity, as well as other events in their lives or history.	

Analysis of texts in this investigation

Text Name	Lexile Measure[1]	Common Core Stretch Grade Band[2]	Mean Sentence Length	Flesch Ease[3]
Introduction	1000	6–8	16.06	64.2
Steps in the investigation	970	4–5	14.38	62.2
TEXT 01 Aristotle's elements	850	4–5	12.52	60
TEXT 02 Lavoisier, "father of modern chemistry"	1000	6–8	13.67	35.5
TEXT 03 Lavoisier's list of chemical elements	960	4–5	14.56	45.7
TEXT 04 Timeline of discovery of elements	1060	6–8	18	28.7
TEXT 05 The periodic table (1871)	1030	6–8	17.20	55.6
TEXT 06 Importance of the periodic table	970	4–5	13.64	35.5
TEXT 07 Elements, baseball bats, and bike frames	1270	9–10	19.64	45.2

[1] Lexile measure indicates the reading demand of the text in terms of its semantic difficulty and syntactic complexity. The Lexile scale generally ranges from 200L to 1700L. The Common Core emphasizes the role of text complexity in evaluating student readiness for college and careers.

[2] We are using the Common Core "stretch" grade bands. The Common Core Standards advocate a "staircase" of increasing text complexity so that students "stretch" to read a certain proportion of texts from the next higher text complexity band.

[3] In the Flesch Reading Ease test, higher scores indicate that the material is relatively easy to read while lower scores indicate greater difficulty. Scores in the 50–70 range should be easily understood by 13- to 15-year-olds, while those in the 0–30 range are appropriate for university graduates.

3
INVESTIGATION

How can looking at the same information from different perspectives pave the way for progress?

Have you ever developed a new point of view? Did you ever see a person or an event or even a school subject differently than you had before? Did you ever hear something new in a familiar song or see something you never saw before in a favorite movie? Did you ever develop a new point of view on a familiar topic?

If so, what affect did it have on you?

In the late 18th century, Antoine Lavoisier, often called the "father of modern chemistry," helped change the way people had viewed the chemical elements. His new point of view started chemists and other scientists down a path of innovation and discovery that led to the world we know today. In fact, some people think that this new way of thinking over 200 years ago led to changes in how we live today.

But how? How can a new way of seeing things pave the way for progress?

This investigation asks you use the documents in the Investigation Library to develop an explanation for how new points of view pave the way for progress. We have provided you with a graphic organizer that you can use to trace a path from Lavoisier to the present. Feel free to explore other influences that are not accounted for in the Investigation Library to create your path. Your teacher might ask you to use your graphic organizer, your notes, and the documents in the Investigation Library to write a four- to five-paragraph essay.

THE STEPS IN THIS INVESTIGATION

How can looking at the same information from different perspectives pave the way for progress?

EXPLORE	Begin with your initial *conjectures* (best guesses) about why and how new points of view or ways of seeing things can pave the way for discovery and progress. Think about examples in your own life or from history when a different point of view opened up new possibilities.
RESEARCH	Read the materials in the Investigation Library about changing points of view about the elements. What do the texts tell you about new ideas in chemistry and their influence on further discovery? How do they support, extend, or contradict your initial conjectures? Do they support, extend, or contradict each other?
	We have provided a table for you to use when you read the documents. Filling in the table will help you capture the information in the texts to answer the question "How do new points of view pave the way for progress?"
SHOW YOUR THINKING	So, now what do you think? Why do new ideas drive new discoveries and progress? Review your initial conjectures, the documents and your notes on the documents, the other course materials, and your table. We have provided a graphic organizer for you to use to help you show your thinking.
	Your teacher might ask you to create a four- to five-paragraph essay that uses the new ideas in chemistry and their influence to explain how a different point of view can promote progress. If you write the essay, please be sure to write a thesis statement that sums up your explanation and then further develop your explanation in the body of the essay and conclusion. Also, try to: • Use big history ideas and content • Refer to the sources from which you're getting your information • Support your thinking with logic and evidence • Write a concluding paragraph to close your argument
	Since most investigations do not end with your answer, please read or discuss your classmates' essays to compare their thinking with yours. Do others students' arguments support, extend, or challenge your explanation?

How can looking at the same information from different perspectives pave the way for progress?

	Main point of the text	Facts you can use to explain how new points of view pave the way for progress
TEXT 01 Aristotle's elements		
TEXT 02 Lavoisier, "father of modern chemistry"		
TEXT 03 Lavoisier's list of chemical elements		
TEXT 04 Timeline of discovery of elements		
TEXT 05 The periodic table (1871)		
TEXT 06 Importance of the periodic table		
TEXT 07 Elements, baseball bats, and bike frames		
ADDITIONAL EXAMPLES		

SHOW YOUR THINKING

How can looking at the same information from different perspectives pave the way for progress?

STEP 01: COMPARE

Aristotle's Point of View on the Elements	⟷	Lavoisier's Point of View on the Elements

Similarities:

Differences:

STEP 02: ARGUE

How did Lavoisier see things differently from Aristotle?

Source(s):

This led to:

How was this progress?

Source(s):

This led to:

How was this progress?

Source(s):

This led to:

How was this progress?

Source(s):

This led to:

3
INVESTIGATION LIBRARY

TEXT 01

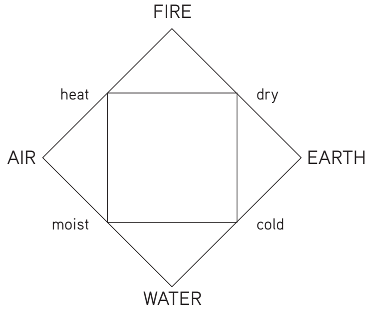
ARISTOTLE'S ELEMENTS

How do think early human beings regarded the material world? What did they think about the elements that made up all matter?

Below we have provided a short explanation provided by John Holmyard, a historian of science and a science teacher in Great Britain. Holmyard describes the point of view of Aristotle (384–322 BCE), a Greek philosopher who studied the natural world. Aristotle's point of view was accepted widely and it survived for over 2,000 years. Many people tried to use it to make discoveries. This view influenced the "alchemists." In many ways, alchemy was an early form of chemistry, but it was based on a mystical understanding of the elements. One goal of alchemists was "transmutation," which means to turn a material object into another object. Alchemists are most famous for their attempts to turn lead into gold.

We have also provided you with a picture of how Aristotle and others could have organized what they thought were the four most basic elements in the world: fire, air, water, and earth.

> According to Aristotle the basis of the material world was in "four elements," fire, air, water, and earth, which are distinguished from one another by their "qualities." The four primary qualities are the fluid (or moist), the dry, the hot, and the cold, and each element possesses two of them. Hot and cold, however, and fluid and dry, are contraries and cannot be coupled; hence the four possible combinations of them in pairs are:
>
> Hot and dry, assigned to fire.
> Hot and fluid (or moist), assigned to air.
> Cold and fluid, assigned to water.
> Cold and dry, assigned to land.
>
> None of the four elements is unchangeable.



THINGS TO THINK ABOUT

Can you see why people might think that everything was made up of earth, water, air, or fire?

Source
Eric John Holmyard, *Alchemy* (Harmondsworth, Middlesex: Penguin Books, 1957) 23.

TEXT 02

LAVOISIER: "FATHER OF MODERN CHEMISTRY"

Most historians of science consider Antoine Lavoisier (1743–1794) the "father of modern chemistry" even though he made his living as a tax collector and not as a scientist. He was a French nobleman who conducted experiments and made many contributions to our collective learning, including our understanding of the elements. Through his experiments he was able to challenge the claim that the world was composed of only four elements: earth, water, air, and fire. For example, he showed that water is actually made up of hydrogen and oxygen. Lavoisier defined an element as substance that cannot be broken down any further.

How did Lavoisier's new definition of an element influence people? In the excerpt below, Eric Scerri, a chemist and philosopher of science at the University of California, Los Angeles, summarizes Lavoisier's contributions to chemistry.

> Lavoisier eliminated some of the vagueness and confusion that dogged the field of chemistry as he found it. The confusion included the chaotic way in which substances were named. It also included uncertain knowledge of weight changes accompanying chemical reactions. Prior to Lavoisier and his contemporaries, people believed that when substances burned they would release a substance called phlogiston. Although some substances do appear to lose weight when they are burned, many others show weight gain. Lavoisier used his personal wealth to commission the making of the finest balances of his day, some of which could measure changes as accurately as one part in 600,000. As a result of his weighing experiments, Lavoisier showed that substances that burned did not in fact give off phlogiston.
>
> Moreover, by accurately weighing reacting substances, Lavoisier could state the law of conservation of matter. This law states: In every chemical operation, an equal quantity of matter exists before and after the operation.
>
> But perhaps Lavoisier's greatest contribution was that he was highly critical of the Greeks' classical abstract element scheme. By adopting an empiricist approach, he attempted to remove any talk of abstract elements or principles in favor of elements as simple substances, which could be isolated and which could not be further decomposed.

Source

Modified excerpt from Eric R. Scerri (2006-10-12), *The Periodic Table: Its Story and Its Significance* (Kindle Locations 733-759). Oxford University Press. Kindle Edition.

TEXT 03

LAVOISIER'S LIST OF CHEMICAL ELEMENTS

Lavoisier wrote *Elements of Chemistry,* which many people consider the first modern chemistry textbook. He also created one of the first tables of elements when he listed all the substances he could not break down into simpler substances. Though he did not create the periodic table, he identified 33 simple elements — many of which we do not consider elements today — and he published them in the list below in 1789. His new point of view about elements inspired other discoveries and other ways to organize the elements, even though we no longer fully agree with Lavoisier's list.

TABLE OF SIMPLE SUBSTANCES.

Simple ſubſtances belonging to all the kingdoms of nature, which may be conſidered as the elements of bodies.

New Names.	*Correſpondent old Names.*
Light	Light.
Caloric	Heat. Principle or element of heat. Fire. Igneous fluid. Matter of fire and of heat.
Oxygen	Dephlogiſticated air. Empyreal air. Vital air, or Baſe of vital air.
Azote	Phlogiſticated air or gas. Mephitis, or its baſe.
Hydrogen	Inflammable air or gas, or the baſe of inflammable air.

Oxydable and Acidifiable ſimple Subſtances not Metallic.

New Names.	*Correſpondent old names.*
Sulphur Phoſphorus Charcoal	The ſame names.
Muriatic radical Fluoric radical Boracic radical	Still unknown.

Oxydable and Acidifiable ſimple Metallic Bodies.

New Names.		*Correſpondent Old Names.*
Antimony	Regulus of	Antimony.
Arſenic		Arſenic.
Biſmuth		Biſmuth.
Cobalt		Cobalt.
Copper		Copper.
Gold		Gold.
Iron		Iron.
Lead		Lead.
Mangaueſe		Manganeſe.
Mercury		Mercury.
Molybdena		Molybdena.
Nickel		Nickel.
Platina		Platina.
Silver		Silver.
Tin		Tin.
Tungſtein		Tungſtein.
Zinc		Zinc.

THINGS TO THINK ABOUT

Can you identify substances on Lavoisier's list that we no longer consider elements? For example, is "light" an element? And can you identify substances on Lavoisier's list that are still on the periodic table?

Source

Antoine Lavoisier, *Elements of Chemistry* (Edinburgh: G.G. & J. Robinson, and T. Kay, 1795).

TEXT 04

TIMELINE OF DISCOVERY OF ELEMENTS

The following table shows the discovery of elements before and after Lavoisier published his ideas on the elements.

Time of Discovery	Elements Discovered	Total Number
Before 500 C.E.	Gold, Silver, Copper, Iron, Tin, Lead, Antimony, Mercury, Sulfur, Carbon	10
500 CE–1730	Arsenic, Bismuth, Zinc, Phosphorous, Potassium	5
1730–1739	Cobalt	1
1740–1749		0
1750–1759	Magnesium, Nickel	2
1760–1769	Hydrogen	1
1770–1779	Nitrogen, Oxygen, Chlorine, Manganese, Molybdenum	5
1780–1789	Zirconium, Tellurium, Tungsten, Uranium	4
Lavoisier's New Point of View on Elements (1789)		
1790–1799	Beryllium, Titanium, Chromium, Strontium, Yttrium	5
1800–1809	Boron, Sodium, Potassium, Calcium, Vanadium, Niobium, Rhodium, Palladium, Barium, Cerium, Tantalum, Osmium, Iridium	13
1810–1819	Lithium, Selenium, Cadmium, Iodine	4
1820–1829	Aluminum, Silicon, Bromine, Thorium	4
1830–1839	Lanthanum	1
1840–1849	Ruthenium, Terbium, Erbium	3
1850–1859		0
1860–1869	Rubidium, Indium, Caesium, Thallium	4
1870–1879	Scandium, Gallium, Samarium, Holmium, Thulium, Ytterbium	6
1880–1889	Germanium, Fluorine, Praseodymium, Gadolinium, Dysprosium	5
1890–1899	Helium, Neon, Argon, Krypton, Xenon, Neodymium, Polonium, Radium, Actinium	9
1900–1909	Europium, Lutetium, Radon	3
1910–1919	Protactinium	1
1920–1929	Hafnium, Rhenium	2
1930–1939	Technetium, Francium	2
1940–1949	Promethium, Astatine, Neptunium, Plutonium, Americium, Curium, Berkelium	7
1950–1959	Californium, Einsteinium, Fermium, Mendelevium, Nobelium	5
1960–1969	Actinides, Rutherfordium, Dubnium	3
1970–1979	Seaborgium, Bohrium	2
1980–1989	Hassium, Meitnerium	2
1990–1999	Darmstadtium, Roentgenium, Copernicium	3

Source: Compiled from http://www.pse.merck.de/merck.php?lang=EN.

TEXT 05

THE PERIODIC TABLE (1871)

By 1860, humans had discovered around 60 elements and some people began to see new patterns in the elements. For example, they noticed similarities when they used atomic weight to arrange the elements.

Russian chemist Dmitri Mendeleev (1834–1907) listed the properties of the elements and placed them on flash cards. He then sorted the cards like he was playing the card game solitaire. At one point, he even pinned the cards to a wall and stood back to see if a pattern emerged. Eventually, he proposed a "periodic" table of columns and rows similar to the one we use today.

Mendeleev was not the only one to propose this model of the periodic table but he was the only one to leave gaps or spaces on his table to make room for the discovery of new elements. Thus he was predicting that people would discover new elements and where the new elements would fit on the periodic table. The dashes in the table represent unknown elements in 1871, when it was published.

Reihen	Gruppo I. — R^2O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fo=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	So=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	To=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

Mendeleev's 1871 periodic table

TEXT 06

IMPORTANCE OF THE PERIODIC TABLE

What made Mendeleev's periodic table and new system to arrange the elements so important? To explain, we have taken an excerpt from Michelle Feder's biography of Mendeleev, which is in Unit 3 of the Big History Project course site.

> [Mendeleev] used the patterns in his table to predict the properties of the elements he thought must exist but had yet to be discovered. He left blank spaces in his chart as placeholders to represent those unknown elements. When the gap was in the middle of a triad, or trio of elements bearing similar characteristics, he would guess at the hypothetical element's atomic mass, atomic number, and other properties. Then he named these with the prefix *eka*, meaning "first" in Sanskrit. For instance, the predicted element designated as "eka-aluminum," he located below the known element aluminum. It was later identified as gallium.
>
> Gallium, germanium, and scandium were all unknown in 1871, but Mendeleev left spaces for each and predicted their atomic masses and other chemical properties. Within 15 years, the "missing" elements were discovered, conforming to the basic characteristics Mendeleev had recorded. The accuracy of those predictions led to the periodic table's acceptance.

TEXT 07

ELEMENTS, BASEBALL BATS, AND BIKE FRAMES

How could a point of view proposed in 1789 possibly help change the bats we use to play baseball or the bikes we ride?

Read the excerpt below, by Sam Kean, a writer in Washington, D.C. Kean makes an interesting connection between some of the elements that Mendeleev predicted people would discover. Kean's work has appeared in the *New York Times Magazine* and on *Slate*, and has been featured on National Public Radio's *All Things Considered*. His book about major changes in chemistry, *The Disappearing Spoon*, was a *New York Times* national best-seller.

How does his description support, extend, or challenge your thinking about how new points of view pave the way for progress?

> Three of every four elements are metals, but beyond iron, aluminum, and a few others, most did nothing but plug holes in the periodic table before World War II.... But since about 1950, every metal has found a niche. Gadolinium is perfect for magnetic resonance imaging (MRI). Neodymium makes extremely powerful lasers. Scandium, now used as a tungsten-like additive in aluminum baseball bats and bike frames, helped the Soviet Union make lightweight helicopters in the 1980s. It purportedly even topped Soviet ICBM [intercontinental ballistic] missiles stored underground in the Arctic, to help the nukes punch through sheets of ice.

Source

Sam Kean, *The Disappearing Spoon: And Other Tales of Madness, Love, and the History of the World from the Periodic Table of the Elements* (New York: Oxford University Press, 2011) 94.