Change You Can Believe In

MI HSCE

C1.1D Identify patterns in data and relate them to theoretical models.
C1.1E Describe a reason for a given conclusion using evidence from an investigation.
C5.2C Draw pictures to distinguish the relationships between atoms in physical and chemical changes.

NSES

Content Standard B:

The physical properties of compounds reflect the nature of the interactions among its molecules. The interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them. (9-12)

TYPE OF INQUIRY

Guided

TIME

NOTE: This activity is intended to be the first portion of a two-part experience for students. This first activity is intended to establish a particulate-level understanding of physical and chemical changes, while the second part, The Only Thing Constant in Life is Change, is intended to establish what macroscopic observations are associated with each of these types of changes. These activities are intended to be used together.

Predictions (Pre-lab, Day 1): 15-20 min
Procedure and Results (Day 2): 25-30 min
Connections to the Real World (Day 2): 20 min
Reflecting on Learning (Possible take home assignment, discuss Day 3): 15 min

EDUCATIONAL OBJECTIVES

The student will construct a particulate-level understanding of the difference between physical and chemical changes.

CONCEPTS ADDRESSED

- chemical processes at the particulate level.
- differences between physical and chemical changes at the particulate level.

MISCONCEPTIONS

"Students prefer to base their categorizations of matter on intuition and not on scientific concepts" (Horton, 2007). Students will construct scientifically-based methods for categorizing physical and chemical changes.

"Students often avoid using atoms and molecules to describe an event as physical or chemical" (Taber, 2002. Students will be forced to consider physical and chemical changes on the particulate level before considering the macroscopic level observations.

"Any time a connection between atoms is changed, a chemical reaction has occurred" (Robinson, 1999). Students will have the opportunity to discuss and debate how physical and chemical changes are defined. This experience should bring about the understanding that the boundaries between physical and chemical changes are not always completely clear. (i.e. NaCl dissolving in water.)

Freezing and boiling are examples of chemical reactions; a phase change is a kind of chemical reaction. Students will learn to consider what types of particulate-level changes are classified as physical instead of simply considering macroscopic observations.

PREREQUISITE KNOWLEDGE

The student must have an understanding of the differences between atoms and molecules as well as how they can be represented at the particulate level. An excellent Target Inquiry activity to address this topic is *Putting The World in a Box*. Students should also be able to describe solids, liquids, and gases on the particulate level. It is not necessary for them to fully understand atomic structure, chemical bonds, or balanced equations. This lab simply provides some initial exposure to these topics.

TEACHER BACKGROUND

The instructor must be well-versed in the *Prerequisite Knowledge* as well. This experience is designed to challenge and clarify student notions about physical and chemical changes. This first activity places an emphasis on thinking about changes on the particulate level. On the particulate level, a chemical change involves bonds between atoms being broken and followed by the atoms reconnecting in a new arrangement, giving rise to a completely different substance than before the change. Difficulty arises in the case of ionic bonds. During the dissolving or melting of an ionic compound these bonds are broken; however, it is not considered a chemical change because a new substance is not formed following the change. A physical change often involves the rearrangement of ions; however, they either remain connected or reconnect in the same way and do not form a difference substance, as in the dissolution of an ionic compound such as sodium chloride. Note that ions are rearranged in a double replacement reaction, and this is considered a chemical change; the formation of gases, precipitates, and molecular compounds are clearly examples of chemical changes. For all types of compounds, a distinction must also be made between a *bond* and an *attraction*, however, this can be difficult in the context of ionic compounds. It can be said that when a substance melts, the particles are no longer rigidly held by one another, but that does not imply that a *chemical* bond is broken. The intent of the two-part approach (particulate first, macroscopic second) is to avoid any relationship with the actual substances involved in these changes until the students have clarified their particulate level understanding of the situation. This activity reveals how the distinction between chemical and physical change has been oversimplified and attempts to address the complexities of these ideas within the scope of a typical high school chemistry course and with an engaging series of hands-on approaches. Undoubtedly, the activities will raise interesting questions that students will ask. In considering how to answer them, use them as opportunities to understand what students are thinking and to help the students themselves clarify their own ideas. Thus, your goal is not to avoid giving actual answers, but instead to guide the students in testing their new knowledge with evidence from the various activity.

SAFETY

There are no safety issues for this exercise.

MATERIALS, PREPARATION, AND DISPOSAL

One set of *Changes in Chemistry* cards per lab group (9 cards each, Lettered A-I)
Refer to the end of this document for color and grayscale versions. These can be laminated or placed in page-protectors for repeated use.)

PRELAB ENGAGEMENT / QUESTIONS

1. Take a moment and think about what the difference between the terms *physical change* and *chemical change* might be in the world of chemistry. Write down how you would describe these two chemistry words.

   THINK, PAIR, SHARE: Allow students a few minutes to answer the above question individually (THINK). Student responses will vary.

   Now, share your ideas with your lab partner(s). How are your ideas the same and how are they different?

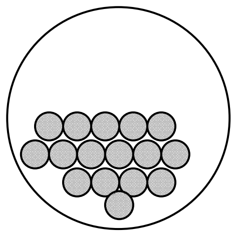
   Students should be instructed to share their ideas with their lab partner(s) (PAIR). Assist groups who are not appropriately sharing and debating their ideas. Rather than providing the students with any evaluation of their ideas, ask them to support their ideas with evidence and/or examples from their experiences.

   Once you've compared your ideas, come to a consensus on what *physical* and *chemical* mean as they relate to chemistry. Be prepared to share your ideas with the class.

   Allow each group to share their ideas (SHARE). Possibly have the students record their answers on the board to facilitate discussion. Guide the class in looking at similarities and differences in the ideas presented. It is not necessary to come to a class consensus on what is the correct definition. This is a good time to point out conflicting ideas and/or interesting things to consider as the activity begins.

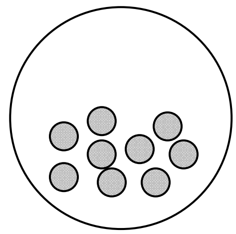
2. In the spaces provided below, sketch how you believe solids, liquids and gases appear on the atomic level. Use a circle,○, to represent an atom. Describe what is happening in each of your drawings.

Solid



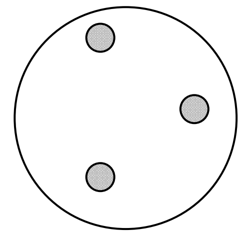
Atoms touching, regular pattern, little movement (vibration).

Liquid



Atoms close, no regular pattern, able to move.

Gas



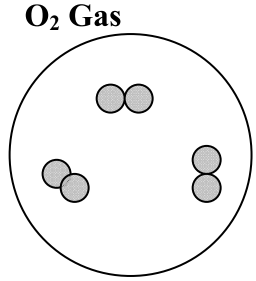
Atoms far apart, free to move.

Discuss your descriptions with your lab partner(s) and be prepared to share your ideas with the class.

This group and class discussion should bring everyone to a consensus as this is necessary prior knowledge.

In a diagram similar to your drawings above, how do you think you should appropriately show two atoms that are "bonded" to each other? In the space provided below, sketch what you think O_2 gas would look like on the atomic level. O_2 means two oxygen atoms are bonded together to form an oxygen molecule.

O_2 Gas



O's touching, spaced like a gas

Discuss your descriptions with your lab partner(s) and be prepared to share your ideas with the class.

The intent here is to check for understanding on how to represent a gas as well as to discuss how a chemical bond will be represented in particulate drawings (atoms touching).

PROCEDURE

You have been provided nine *Changes in Chemistry* cards by your instructor. Each card represents a change that a substance or substances undergo.

Do not give the students the Atom Key! If the students know what the substances in the changes are, they may make their physical/chemical predictions based on the substances' macroscopic behavior and not on the particulate level behavior.

The circle(s) on the left represent the atoms and molecules before they undergo the change and the circle(s) on the right represent the atoms and molecules after they undergo the change.

Your group's task is to categorize each of these changes as "physical" or "chemical." This means you must decide, based on your observations of the changes, what indicates that a physical change has occurred and what indicates that a chemical change has occurred.

Students may struggle with how to begin. They will have to spend time studying the cards and considering what differences exist amongst the cards. Encourage students to consider the results of the discussion on what is "physical" versus "chemical." They probably heard ideas about new substances being formed or bonds being broken.

Allow students to struggle with this stage and only offer guidance when they present you with an incorrect organization system. Before giving guidance, ask the students to explain their reasoning behind their organization. They need to first define for themselves what they're calling a physical change and a chemical change before you can offer them guidance on what to consider next. Frequently students who construct incorrect definitions apply their "rule" or indicators that they have invented in an inconsistent manner. Pointing this out with a particular example that doesn't work in their rule scheme is a useful way to redirect their exploration.

As your group works through categorizing the changes, record your ideas in the *Data and Observations* section. First, describe what seems to be occurring during the change. Once you've decided whether a change is physical or chemical, record your decision. Then, in the space provided, describe why your group decided each change was physical or chemical.

It may be best if the students first go through each card and write a description of how the atomic arrangements change. Some helpful guidance for struggling groups may be to refer them to the idea of bonds discussed with the oxygen gas example and ask them to consider what bonds might have to do with physical and chemical changes.

As students create their categorizations, do not answer the "Is this right?" question! Only attempt to guide groups that are significantly far from the correct direction, such as groups who sort the changes by what color circles are in them.

If students decide to define chemical changes as "bonds being broken," they will categorize the dissolution of sodium chloride (Card G) as a chemical change. This will make an excellent point of discussion later.

DATA (*sample student data*)

Change A Describe the Change: *Two liquids are combined* Type of Change: *Physical* Defend your Decision: *No substances were changed, no elements rearranged.*	**Change F** Describe the Change: *A liquid (not ordered) turns in to a gas (spaced out), no bonds broken* Type of Change: *Physical* Defend your Decision: *No substances were changed, no elements rearranged.*
Change B Describe the Change: *Atoms changed shape, rearranged* Type of Change: *Physical* Defend your Decision: *No substances changed*	**Change G** Describe the Change: *A solid and a liquid combine, solid breaks apart.* Type of Change: *Chemical of Physical* Defend your Decision: *Bonds broken.*
Change C Describe the Change: *A gas and a solid combined to form a new one* Type of Change: *Chemical* Defend your Decision: *Gas bonds broke, new compound formed, bonds broken, change in "charge."*	**Change H** Describe the Change: *An organized substance (solid), becomes unorganized (liquid), no change in bonds* Type of Change: *Physical* Defend your Decision: *No substances were changed, no elements rearranged.*
Change D Describe the Change: *A solid reacts with a liquid, new substance.* Type of Change: *Chemical* Defend your Decision: *New compound formed, bonds broken, change in "charge."*	**Change I** Describe the Change: *Two substances combine to form new substances.* Type of Change: *Chemical* Defend your Decision: *New substances formed, bonds broken.*
Change E Describe the Change: *A solid reacts with a liquid, new substance.* Type of Change: *Chemical* Defend your Decision: *New compound formed, bonds broken, change*	

in "charge."	

RESULTS (*sample analysis*)

Based on your lab group's discussions and decisions write concise, one-sentence descriptions for *physical change* and *chemical change*.

You want the students to write their definitions while avoiding trying to sound like a textbook. These should be useful definitions to them and should have come out of their analysis of the Changes in Chemistry cards.

Physical Change: *When no bonds are broken or formed. When atoms don't get rearranged. When a new substance is not formed.*

Chemical Change: *When bonds are broken or formed. When atoms get rearranged. When new substances are formed.*

You may wish to ask individual groups about their conclusions to help them clarify what they mean. Once students have come up with their definitions, have each group share their ideas and/or write them on the board. Guide the class in looking at similarities and differences in the ideas presented. You may wish to categorize the ideas as there are several appropriate ways of defining the two. You do want to ensure that students who drew inappropriate conclusions modify their thinking. Allow the class to discuss any ideas that might not work and allow the group that presented the idea to defend themselves.

CONNECTIONS TO THE REAL WORLD

Each of the changes you observed represents a real process that you probably have seen or heard about.

Your instructor will provide you with an *Atom Key* to help you identify what processes are occurring in each of the *Changes in Chemistry* cards.

Below are descriptions of each of these processes in some real-world situation. Match each *Changes in Chemistry* card with the appropriate description.

This portion of the activity will require the students to actually determine what the substances are in each of the change cards. They are not expected to know how to name substances at this point, but should be capable of using the names of the elements and how they're connected to match the changes with the descriptions listed below. You may wish to discuss the answers as a class and possibly elicit further discussion on these points.

G Road salt, sodium chloride, is commonly used to de-ice roads during the winter. When road salt dissolves in the water on the road, it reduces the temperature at which the water would freeze. This helps prevent ice from forming on the roads.

E Cars have been made from steel, which is mostly iron, since their introduction into society in the early 20th century. When the iron interacts with oxygen, it forms rust. This problem is accelerated by the wet, salty roads in many cold, winter climates.

B Copper has been used by humans for about 10,000 years. Due to its excellent flexibility and great ability to conduct electricity, copper is used for electrical wires as well as in pipes for plumbing.

C Original camera "flash bulbs" consisted of very fine magnesium filaments. An electrical current, triggered by the camera shutter, heats the filament until it ignites and burns, very quickly and brightly, with the oxygen in the air.

H Before the invention of the refrigerator, perishable food was often kept in ice boxes, which were cooled using blocks of ice. People relied on ice boxes even during the summer months. Ice was often stockpiled in large "ice houses" during the winter and could often be kept from melting until the following winter.

D Henry Cavendish is credited with identifying hydrogen gas as a unique element in 1766. Cavendish produced hydrogen gas by combining a metal, such as magnesium, with a strong acid, such as hydrochloric acid. Hydrogen production soon became useful as balloonists found this "lighter than air" gas quite useful.

I Sodium bicarbonate, commonly known as baking soda, is used to make baked goods light and fluffy. It does so by decomposing to produce water vapor and carbon dioxide gas. This decomposition process is initiated by the presence of an acid, which donates hydrogen ions.

F The first train locomotives were powered by steam. A very hot fire, usually coal powered, heats a large tank of water called a boiler. When the water evaporates and turns to steam, the boiler becomes highly pressurized by the steam. The high pressure steam is then used to push large pistons, which turns the wheels.

A Rubbing alcohol has many uses, most commonly, as an antiseptic for cleaning minor cuts or contaminated surfaces. Household rubbing alcohol is a mixture of isopropanol and water.

REFLECTING ON LEARNING

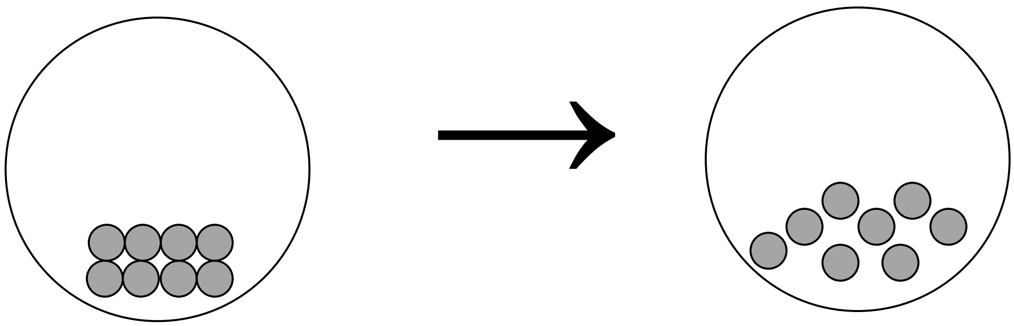
Consider the following two situations. After reading the description, decide whether the change described is physical or chemical, according to the definitions you created. Then, in the space provided, illustrate the change at the particulate level. Use your *Atom Key* in order to consistently represent the particles.

The following is an opportunity for the students to use their newly established concepts of representing physical and chemical changes at the particulate level. It is also an *excellent opportunity for the instructor to gauge student understanding. As students work, ask them how they will represent the state of matter, how they decided the type of change, and what atoms or ions need to be shown as "bonded." Providing colored pencils and an Atom Key to accurately represent the particles will improve the quality of their drawings.*

1. Pure copper can be heated until it melts just below 2000^{o}F. The liquid copper can be poured into molds.

   Physical or Chemical: *Physical, no bonds are broken and no new compounds are formed.*

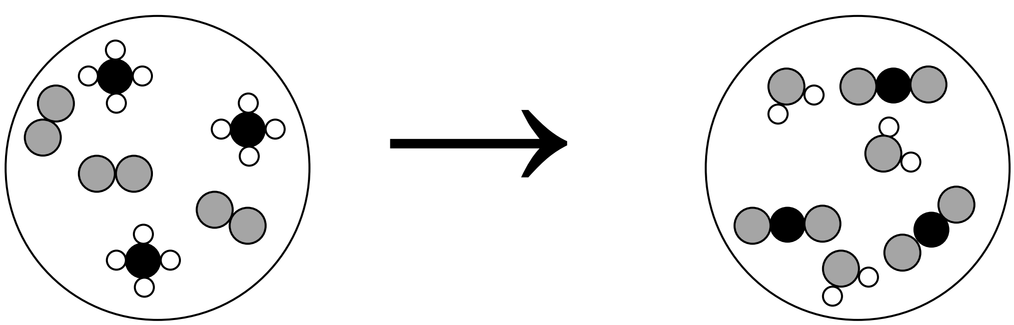
Before After



2. Natural gas consists mostly of methane, CH_4. Natural gas is used to heat homes and cook food. The methane is "burned" by reacting with oxygen, O_2. The products of this reaction are carbon dioxide, CO_2, and water, H_2O.

   Physical or Chemical: *Chemical, the atoms are broken apart and reassembled differently.*

Before After



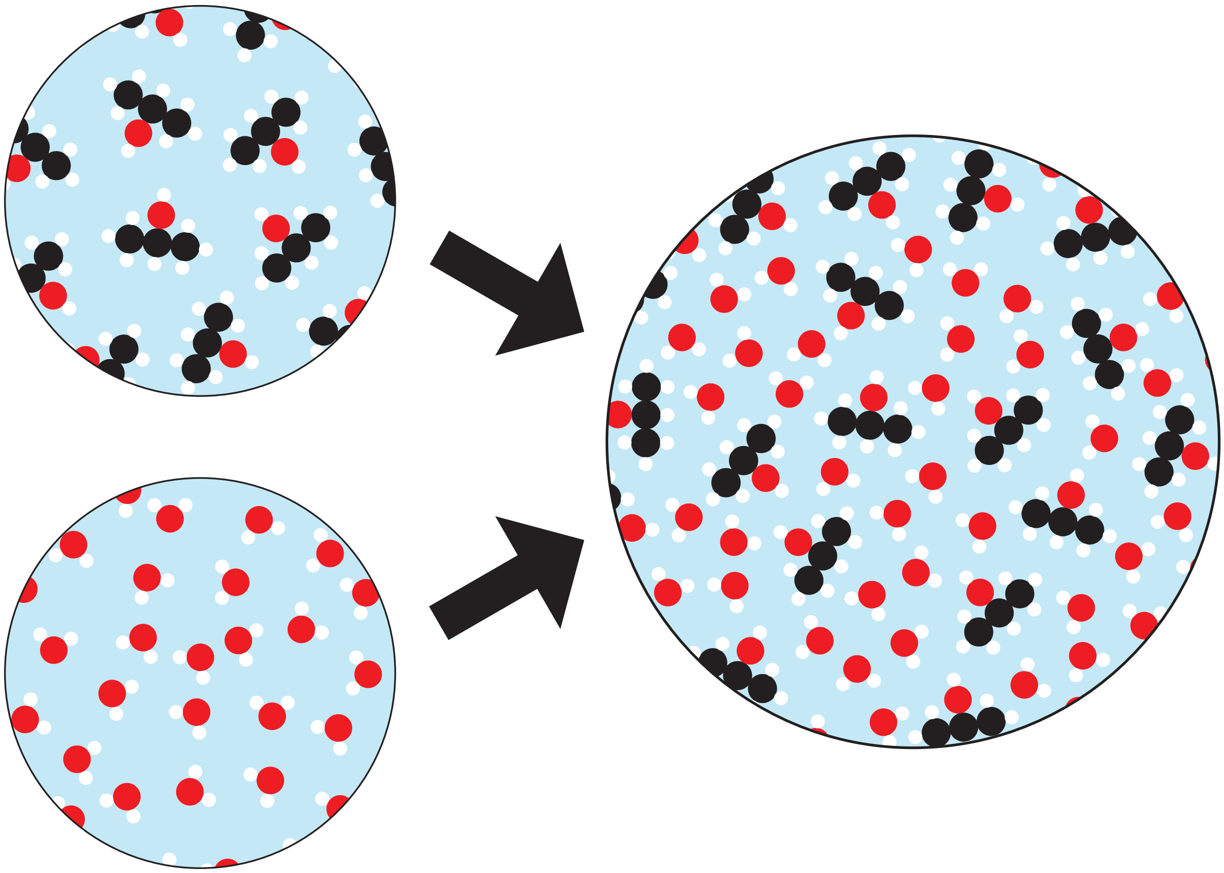
REFERENCES

Horton, C. (2007). Student alternative conceptions in chemistry. *California Journal of Science Education*, *7*(2), 103-136.

Robinson, W. R. (1999). A view of the science education research literature: Student understanding of chemical change. *Journal of Chemical Education, 76*(3), 297-298.

Taber, K. (2002). *Chemical misconceptions-prevention, diagnosis and cure* (Vol 1). London: Royal Society of Chemistry.

A



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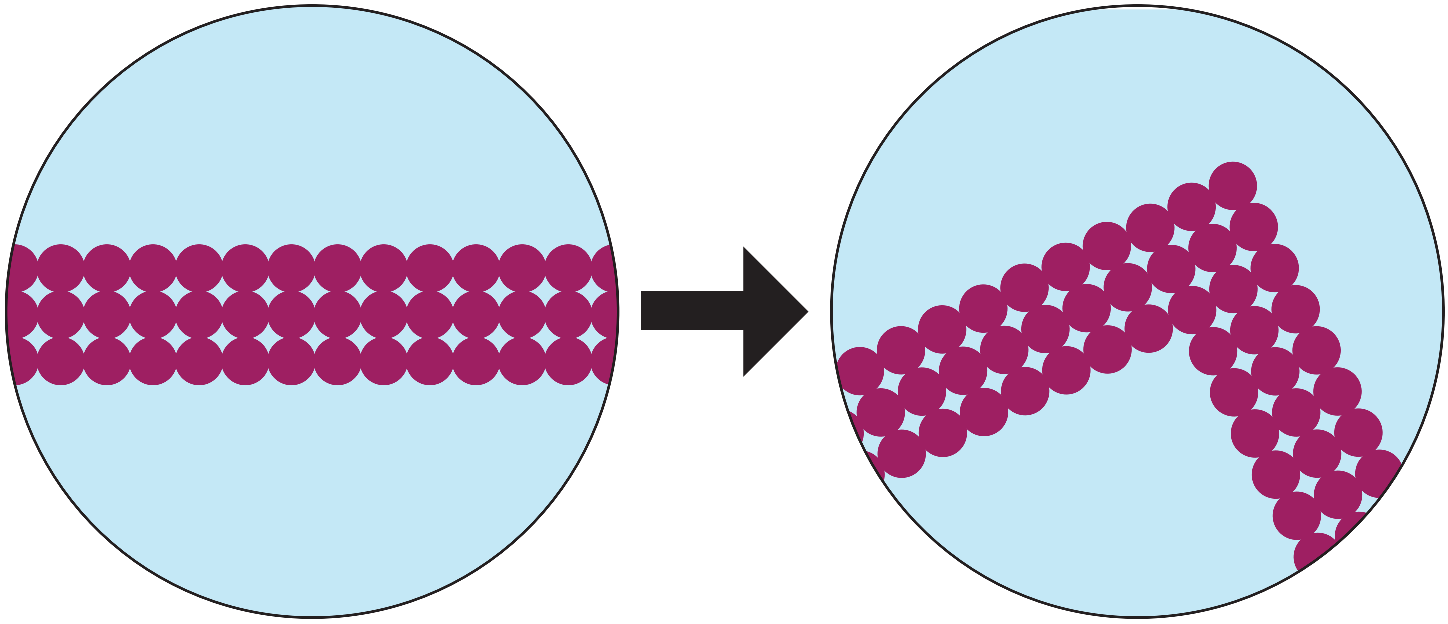

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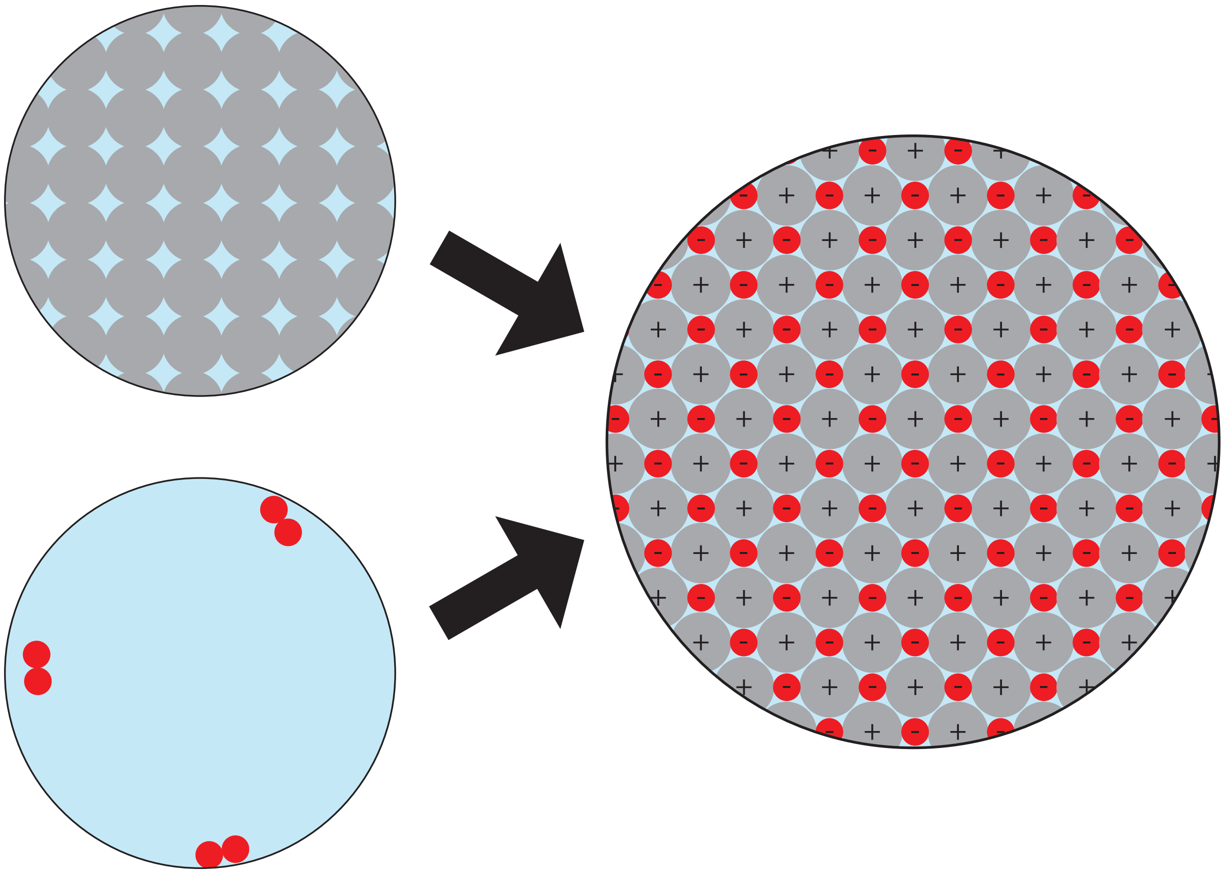

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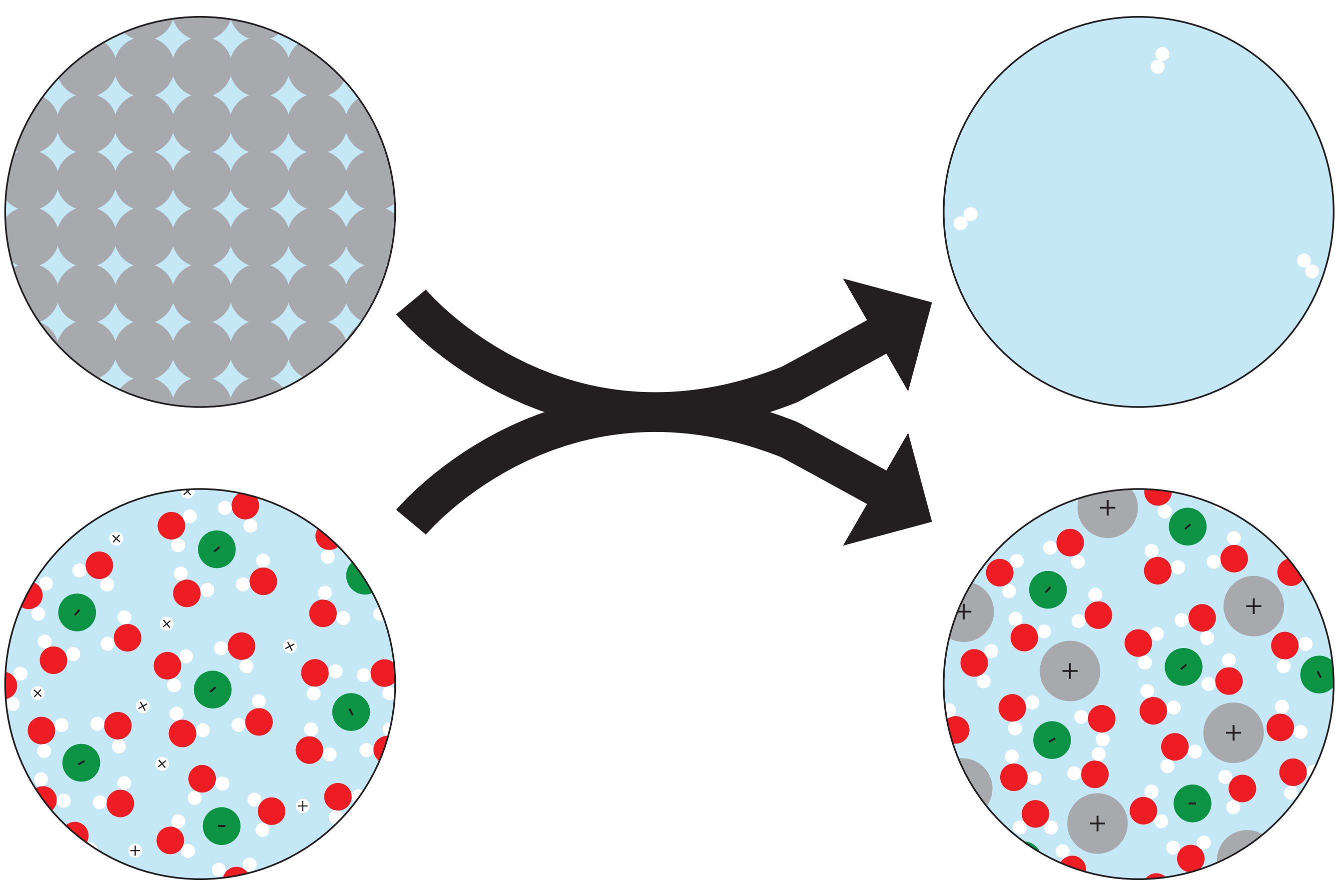

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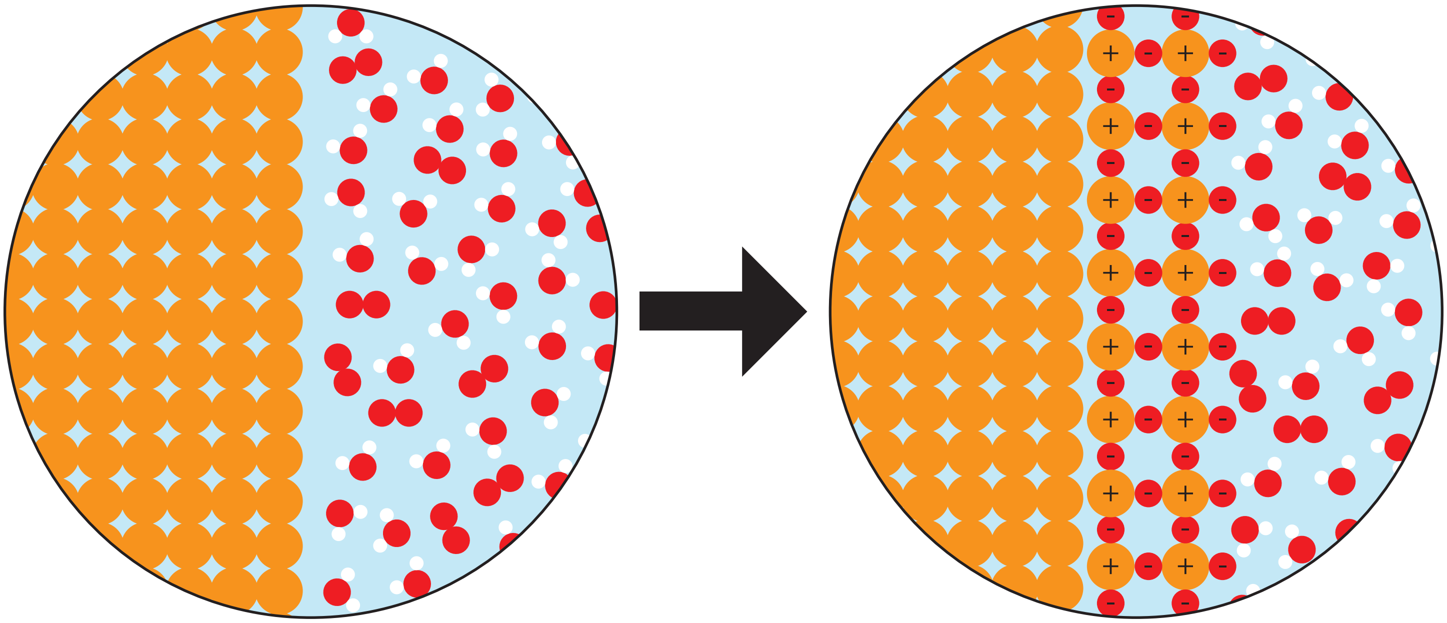

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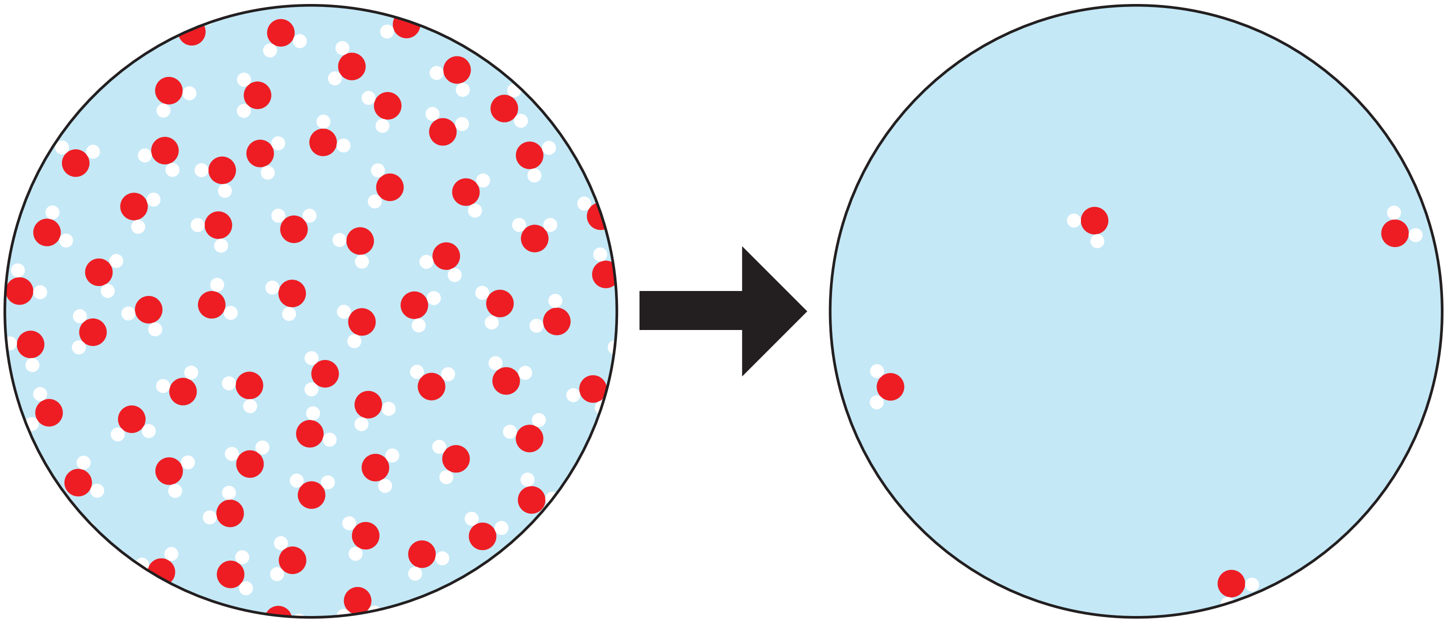

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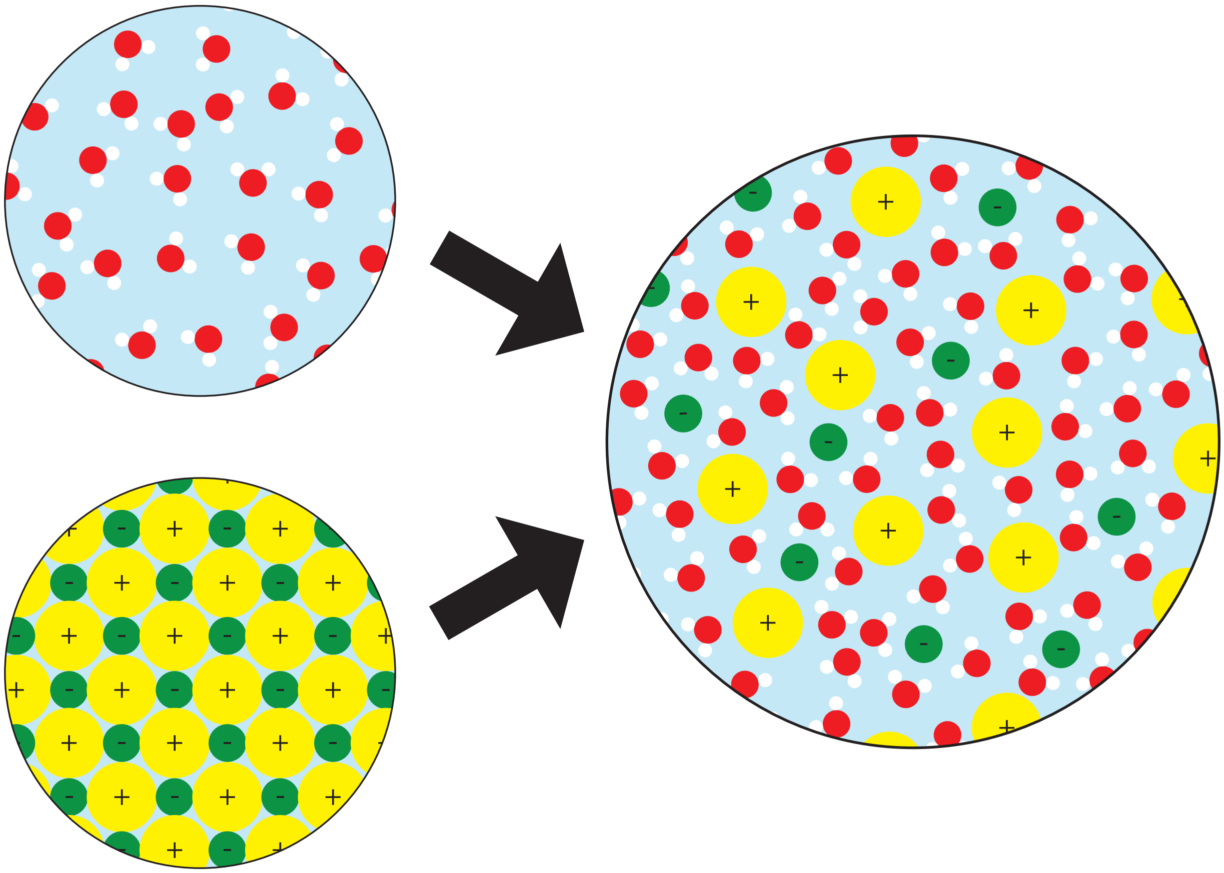

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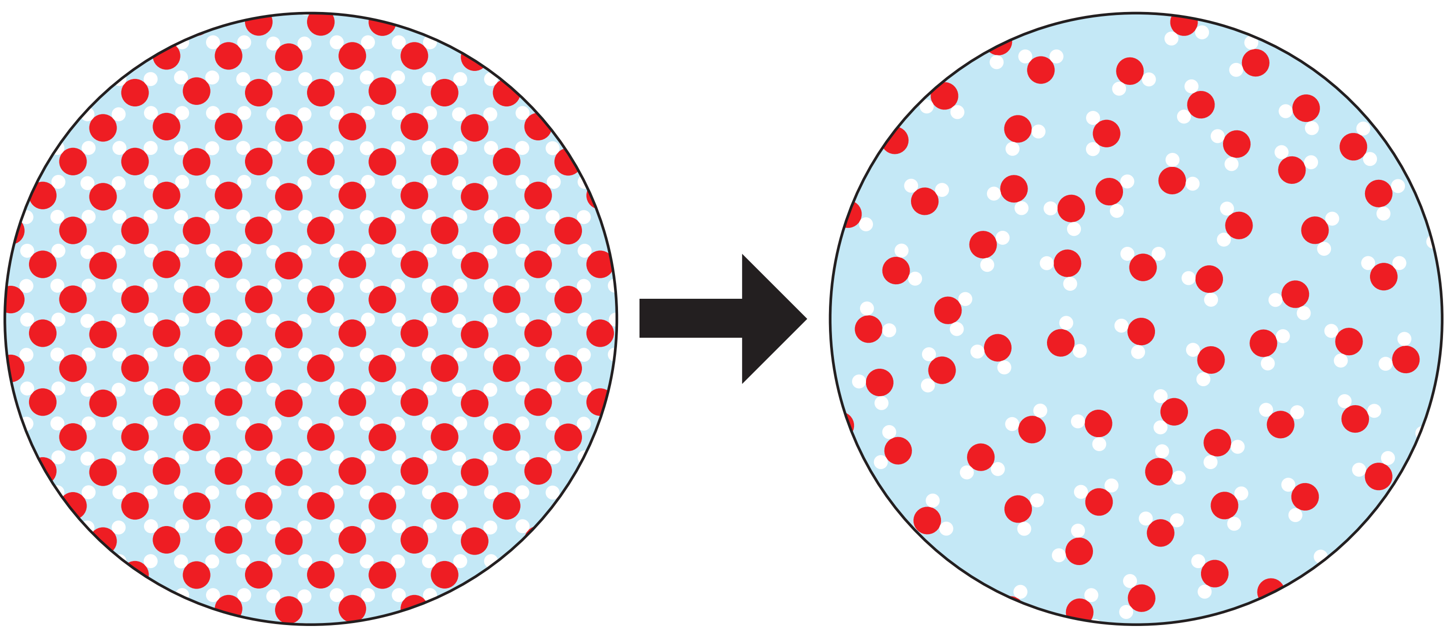

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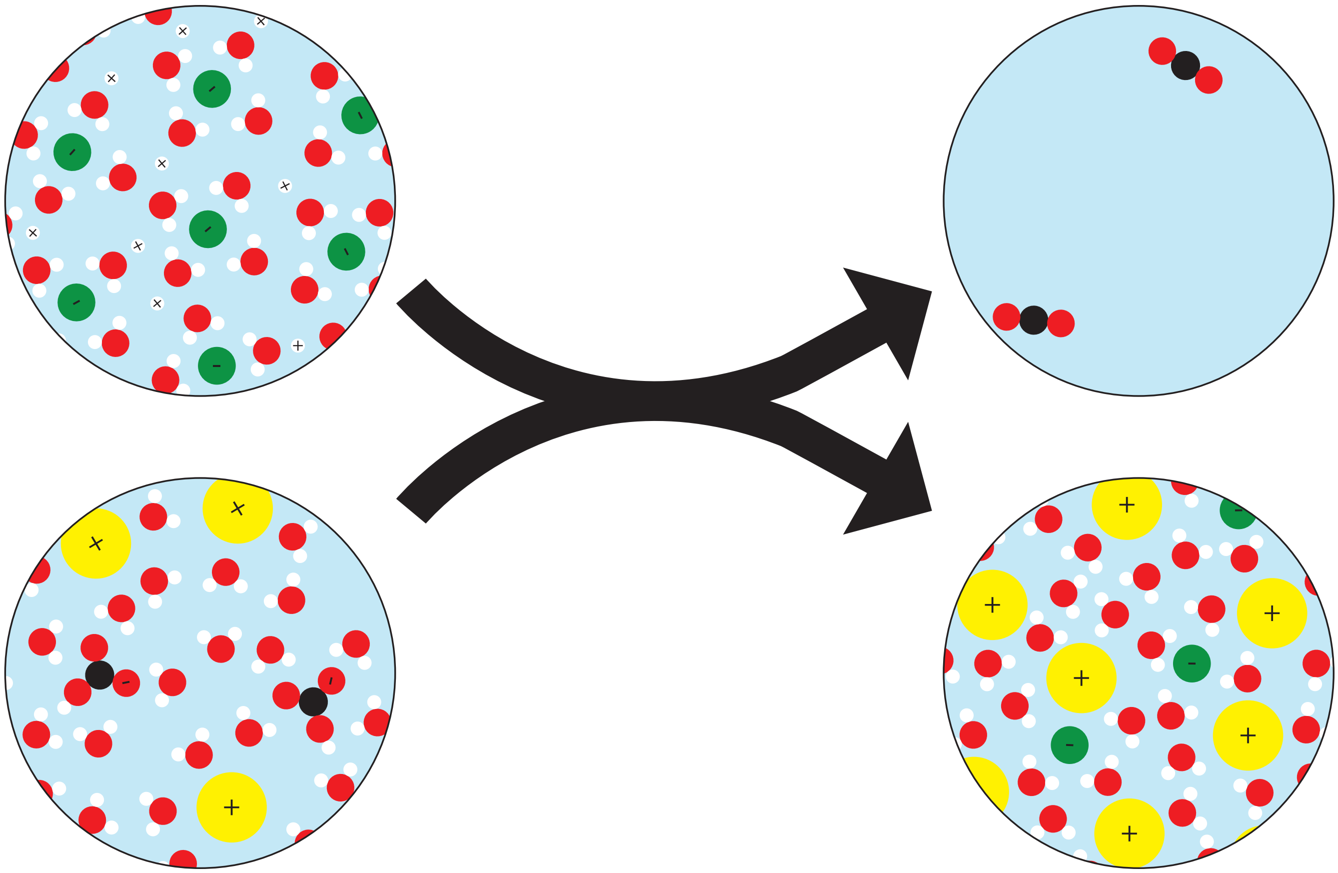
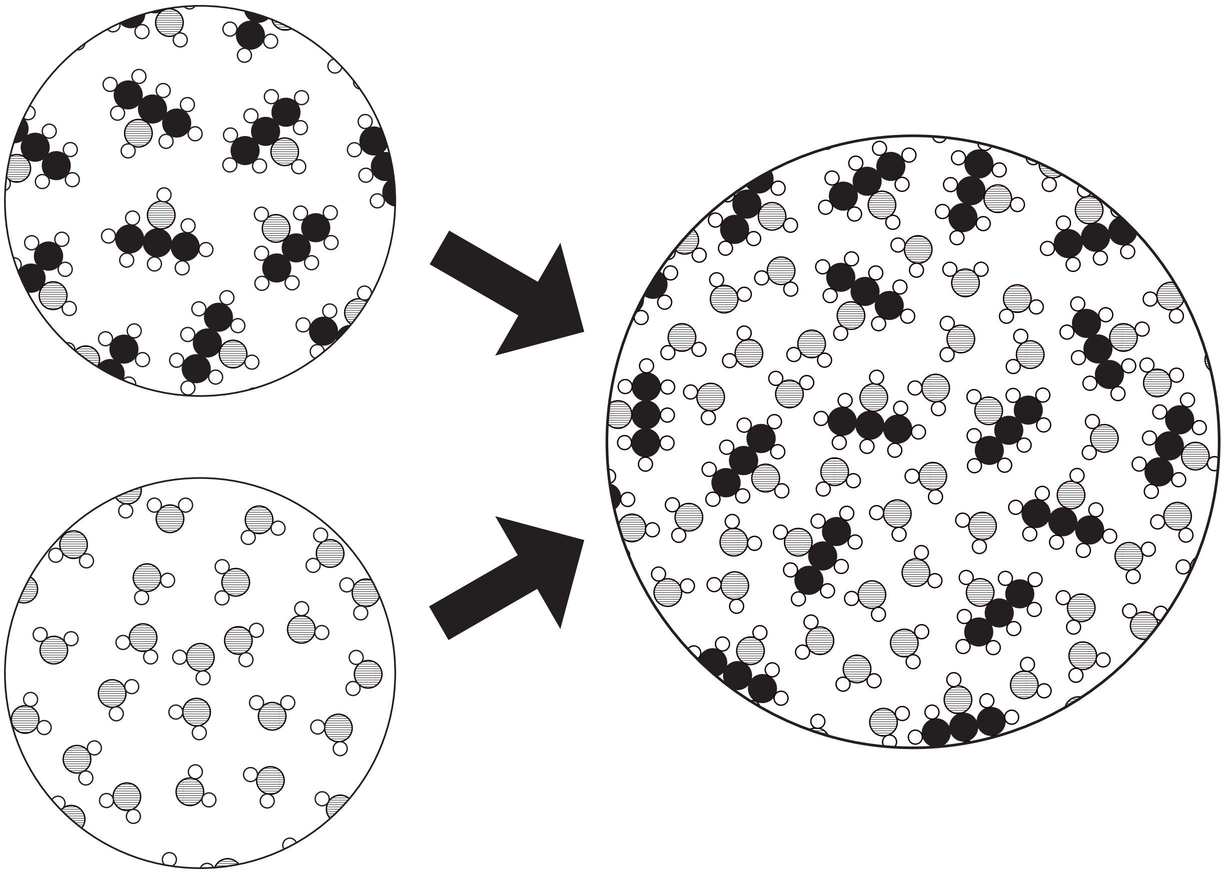


Atom Key

C carbon	Fe iron
Cl chlorine	Mg magnesium
Cu copper	O oxygen
H hydrogen	Na sodium

A



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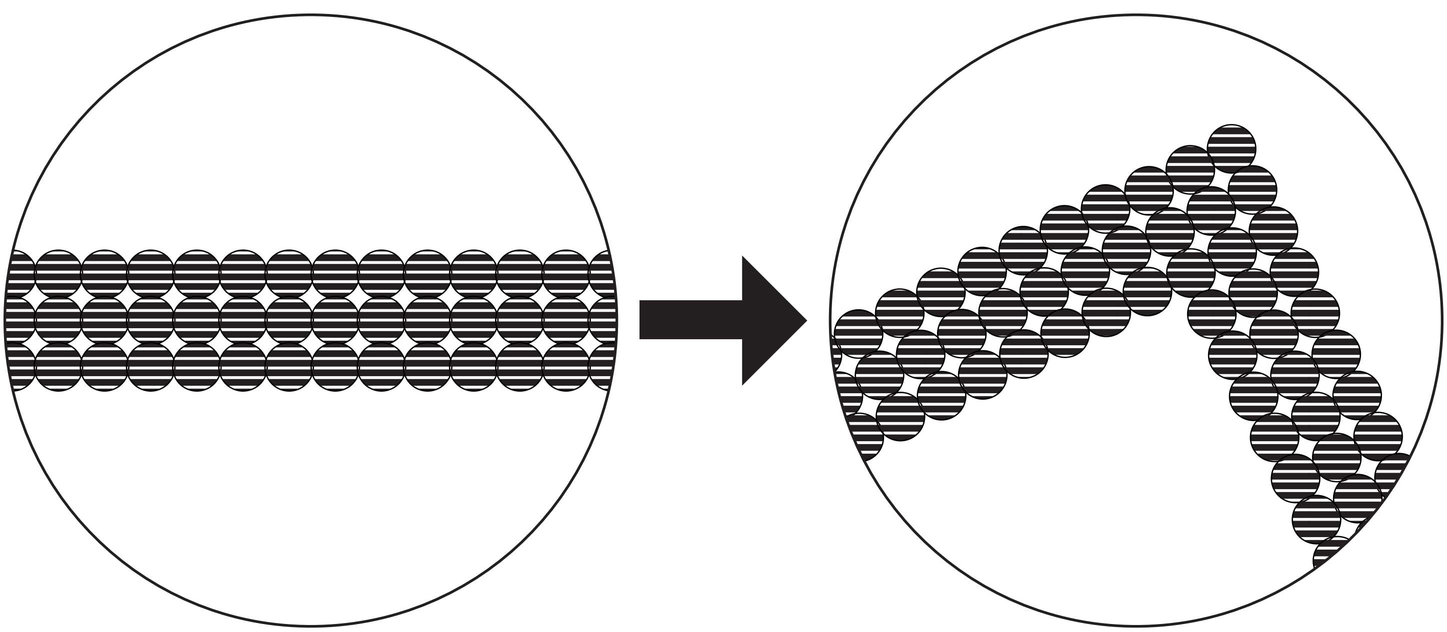

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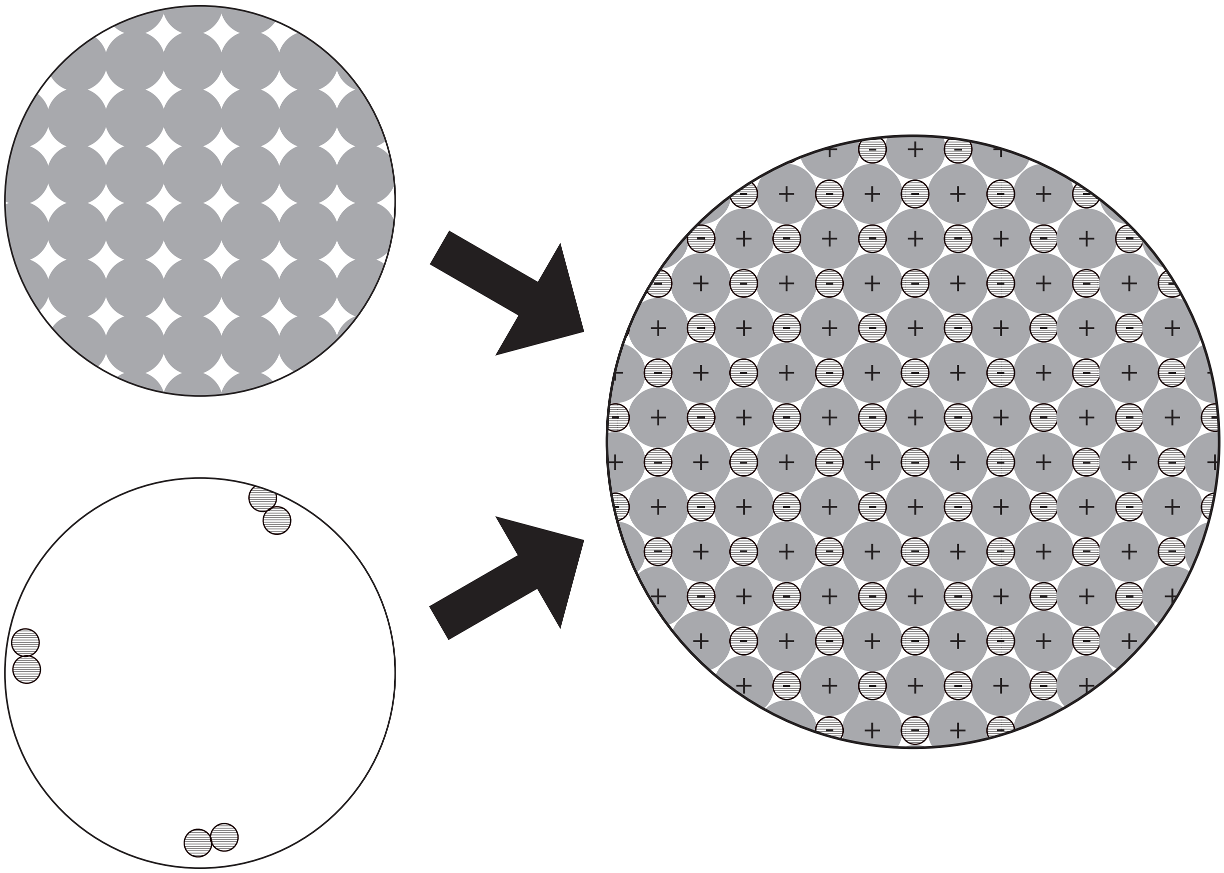

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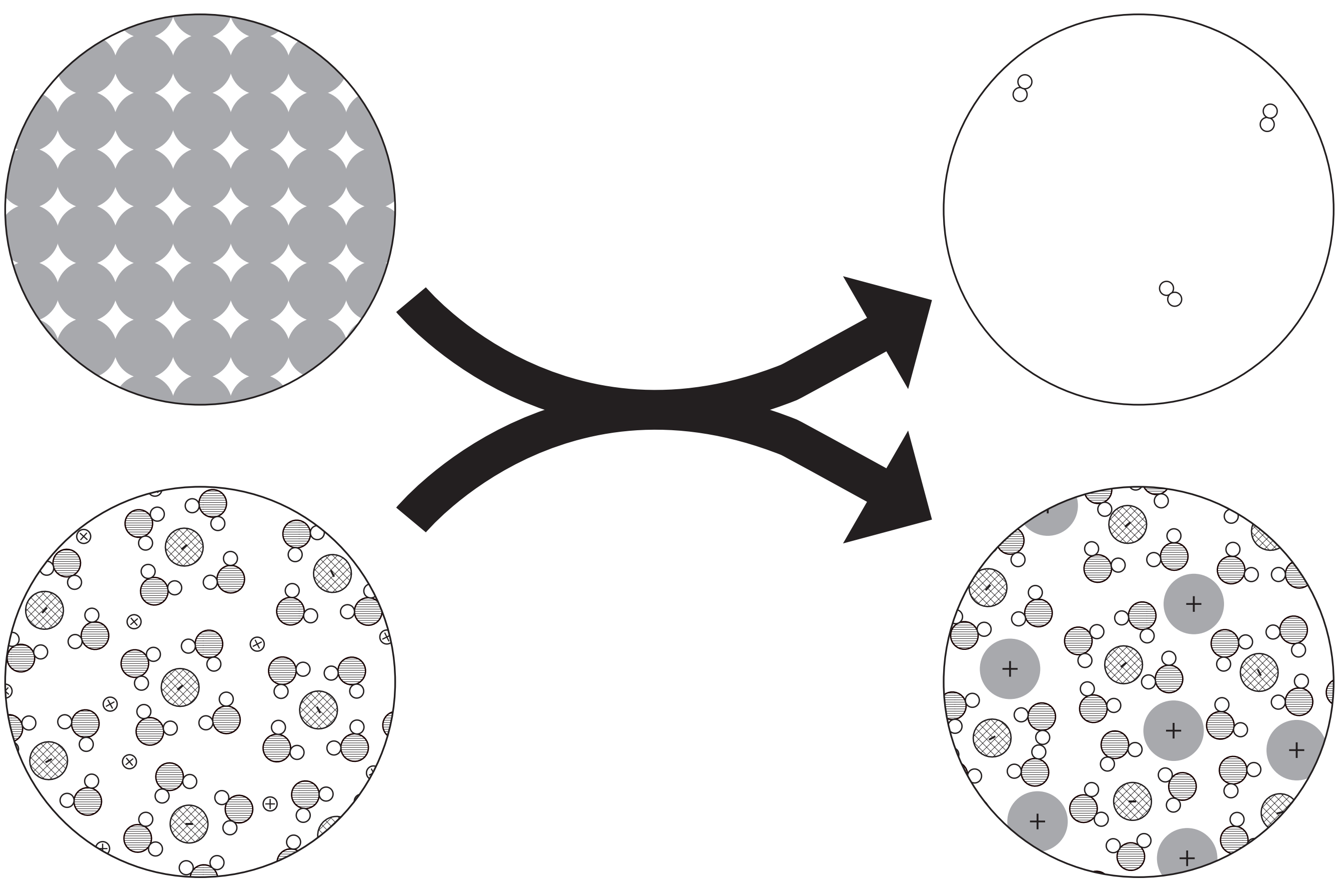

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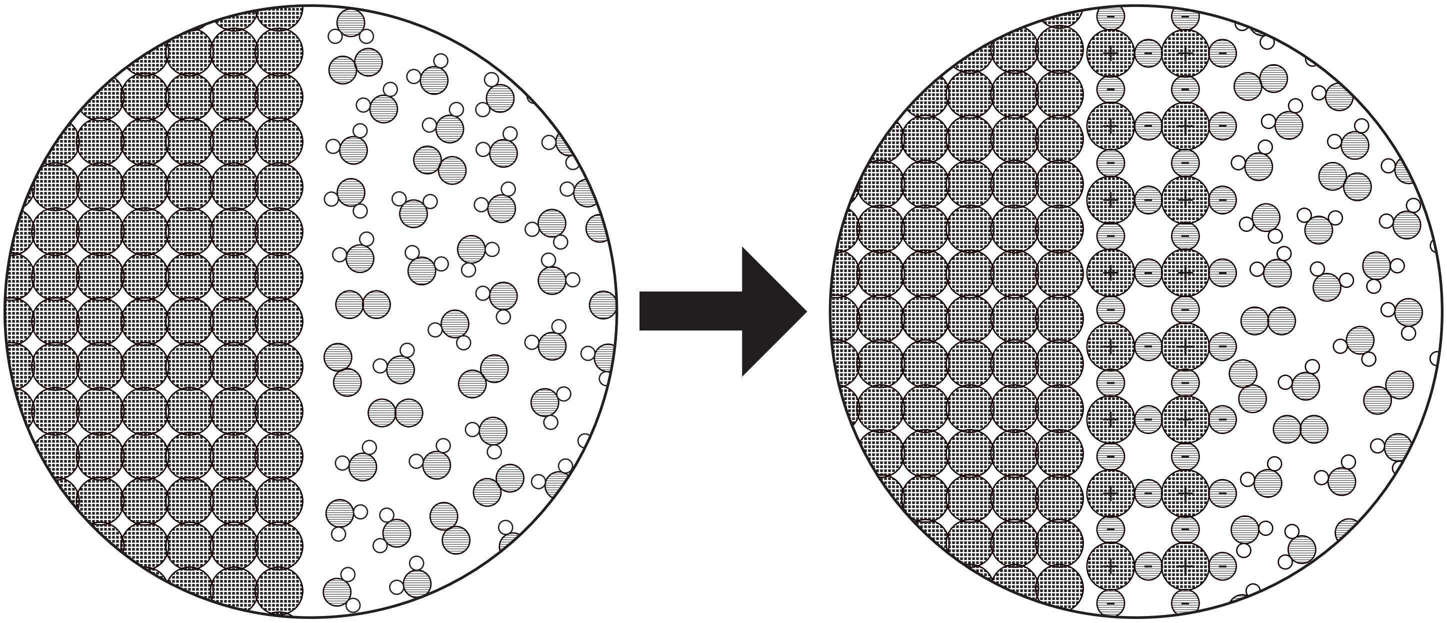

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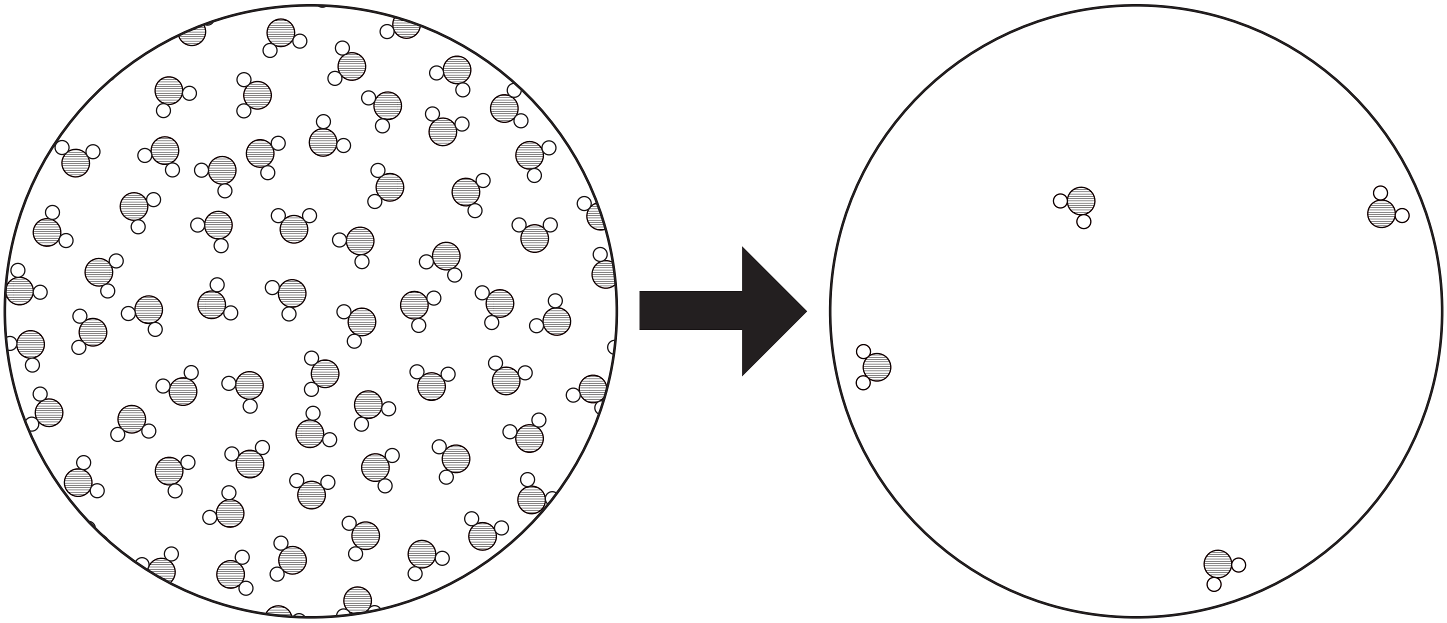

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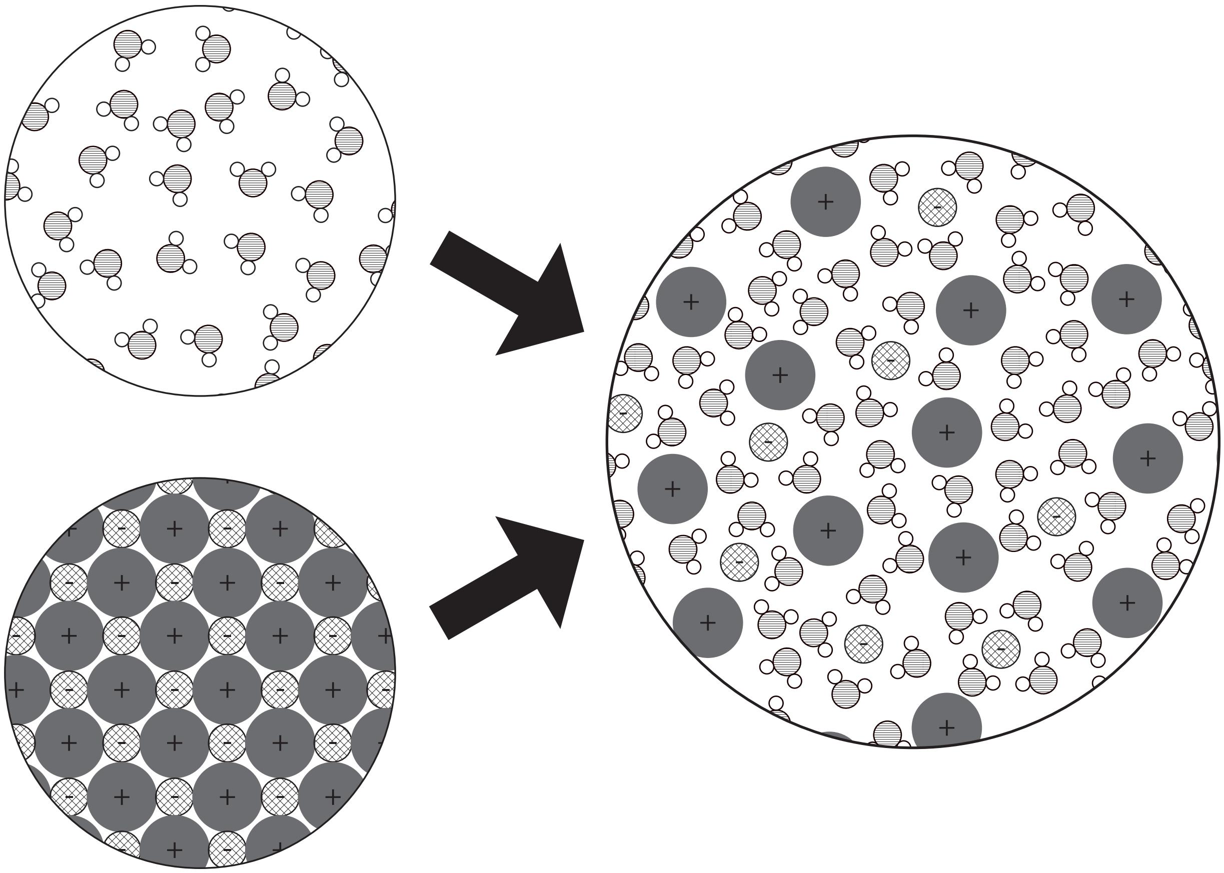

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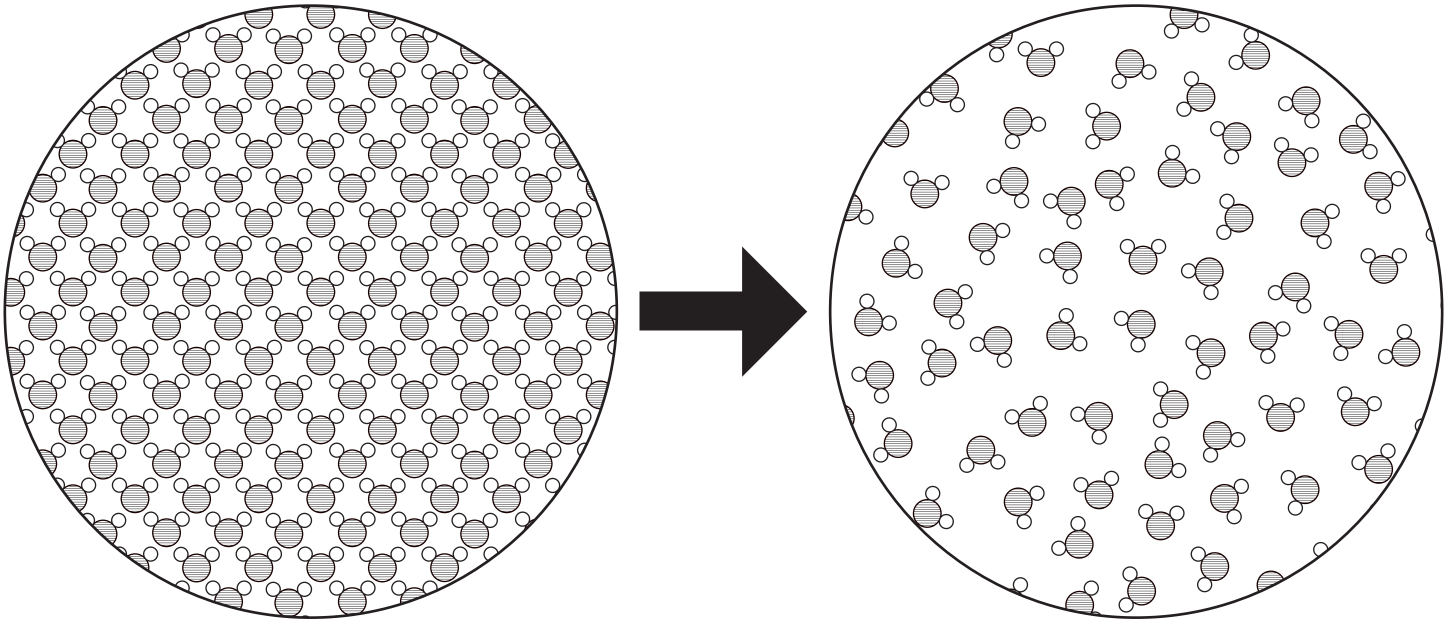

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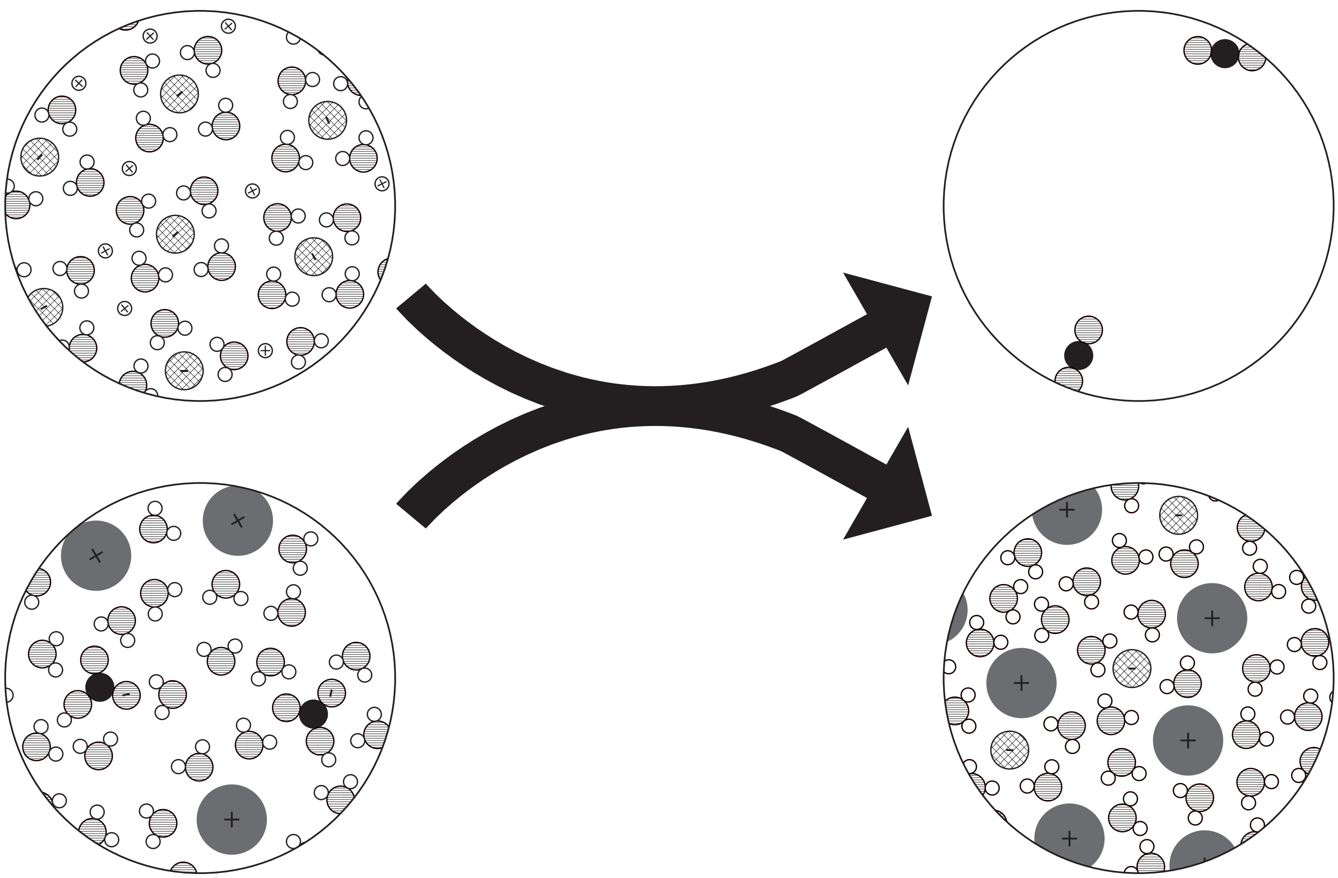

Atom Key

- C carbon
- Cl chlorine
- Cu copper
- H hydrogen
- Fe iron
- Mg magnesium
- O oxygen
- Na sodium