NAME PERIOD DATE

MODELING CHEMISTRY

Initial Question

Exploring chemical and physical changes in a laboratory experiment is not as easy as one may think. The general appearance of a substance can tell us something about events on the molecular level, but this provides limited information. Measuring parameters like conductivity, temperature, pH, or pressure with digital sensors can provide data that helps us understand more about what is going on, but even that may not be enough to completely understand that which is too small to see. This is the challenge of being a chemist.

What tools allow us to examine physical and chemical changes?

Materials and Equipment

Model 1

- Data collection system
- Temperature sensor
- pH sensor
- Conductivity sensor
- Graduated cylinder, 100-mL
- Beakers (6), glass, 100-mL
- Stirring rod
- Unknowns 1A–1D , 100 mL each
- Distilled water wash bottle

Model 2

- Data collection system
- Absolute pressure sensor[1,3]
- Tubing and tubing connector (2)
- Quick release connector
- Sensor extension cable
- Test tube rack
- Test tubes (2), 20mm × 150 mm, glass
- Rubber stopper, #2, two-hole
- Syringe, 10-mL, to fit stopcock
- Stopcock to fit two-hole stopper
- Graduated cylinder, 10 mL
- Unknown 2A, 2 mL
- Unknown 2B, fill approximately 1/4 of the test tube
- Glycerin, several drops
- Tongs
- Paper towel

Model 3

- Data collection system
- Temperature sensor
- pH sensor
- Conductivity sensor
- Graduated cylinder, 100-mL
- Beaker, glass, 100-mL
- Stirring rod
- Distilled water, 50 mL
- Distilled water wash bottle
- Each group is assigned one of the following:
  Sucrose ($C_{12}H_{22}O_{11}$), about 0.5 g
  Sodium chloride (NaCl), about 0.5 g
  Sodium acetate ($NaCH_3COO$), about 0.5 g
  Calcium (Ca) metal turning, about the size of half a pea
  Ammonium nitrate (NH_4NO_3), about 0.5 g

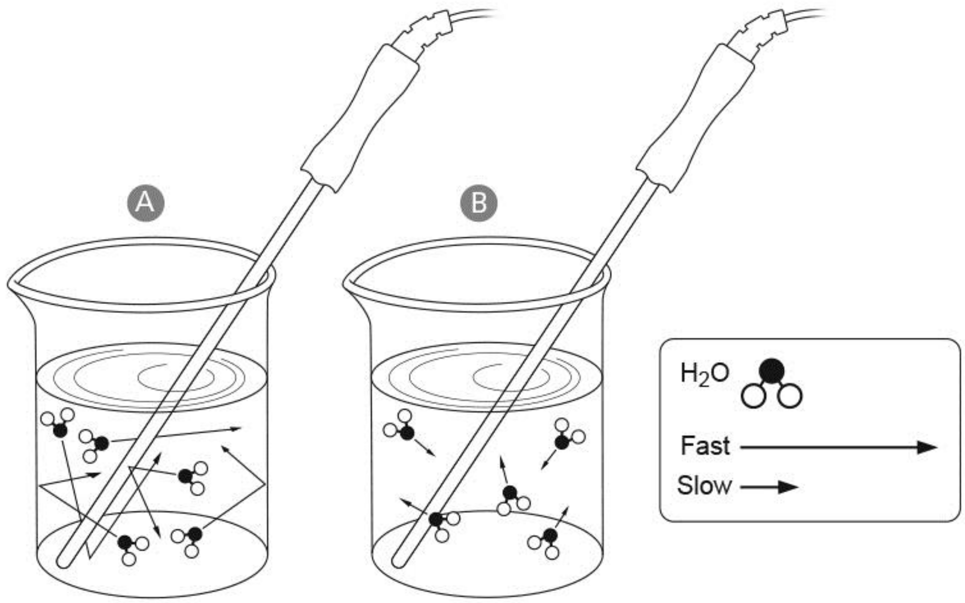
Safety

Add these important safety precautions to your normal laboratory procedures:

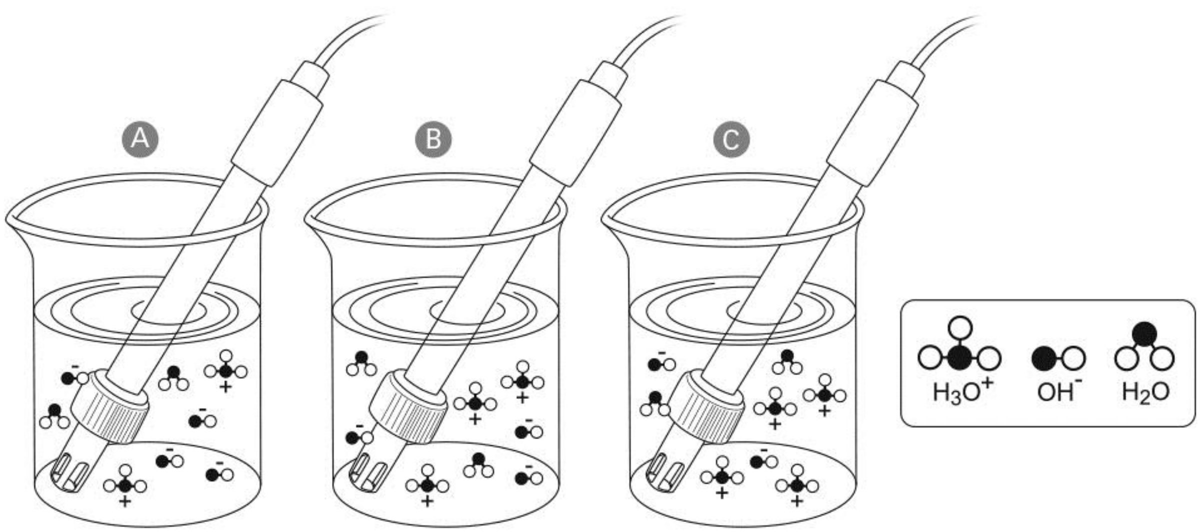
- Treat all unknowns as a hazardous, toxic, and harmful material.
- All unknowns should be disposed of in the proper waste container.
- Some of the unknowns in this lab are flammable. No unknowns should be used around an open flame.

Getting Your Brain in Gear

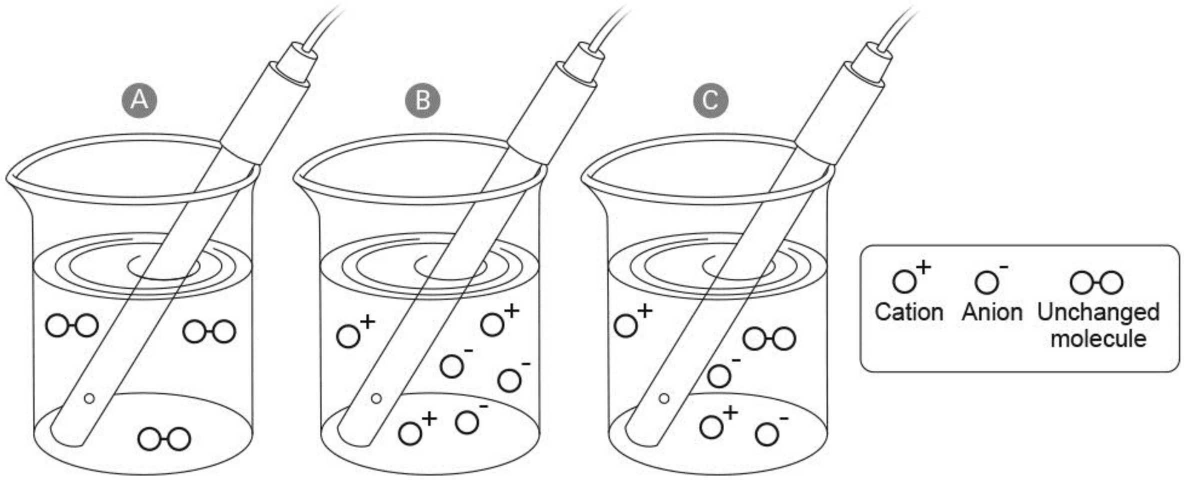
1. In this lab you use a temperature probe. Consider the following particulate-level representations. Which beaker contains the hot water and which contains the cold water? Explain your reasoning.



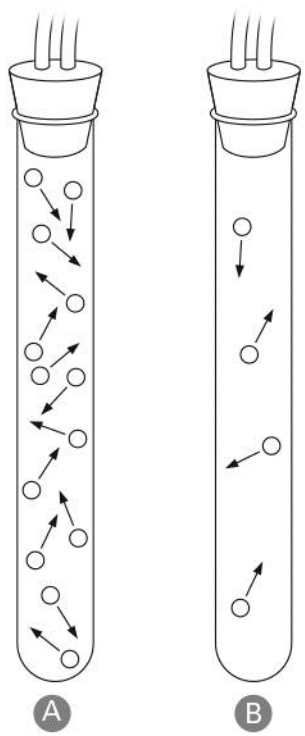
2. In this lab you use a pH sensor. Consider the following particulate-level representations. Label the beakers as “Acid”, “Base”, or “Neutral”. Explain your reasoning.



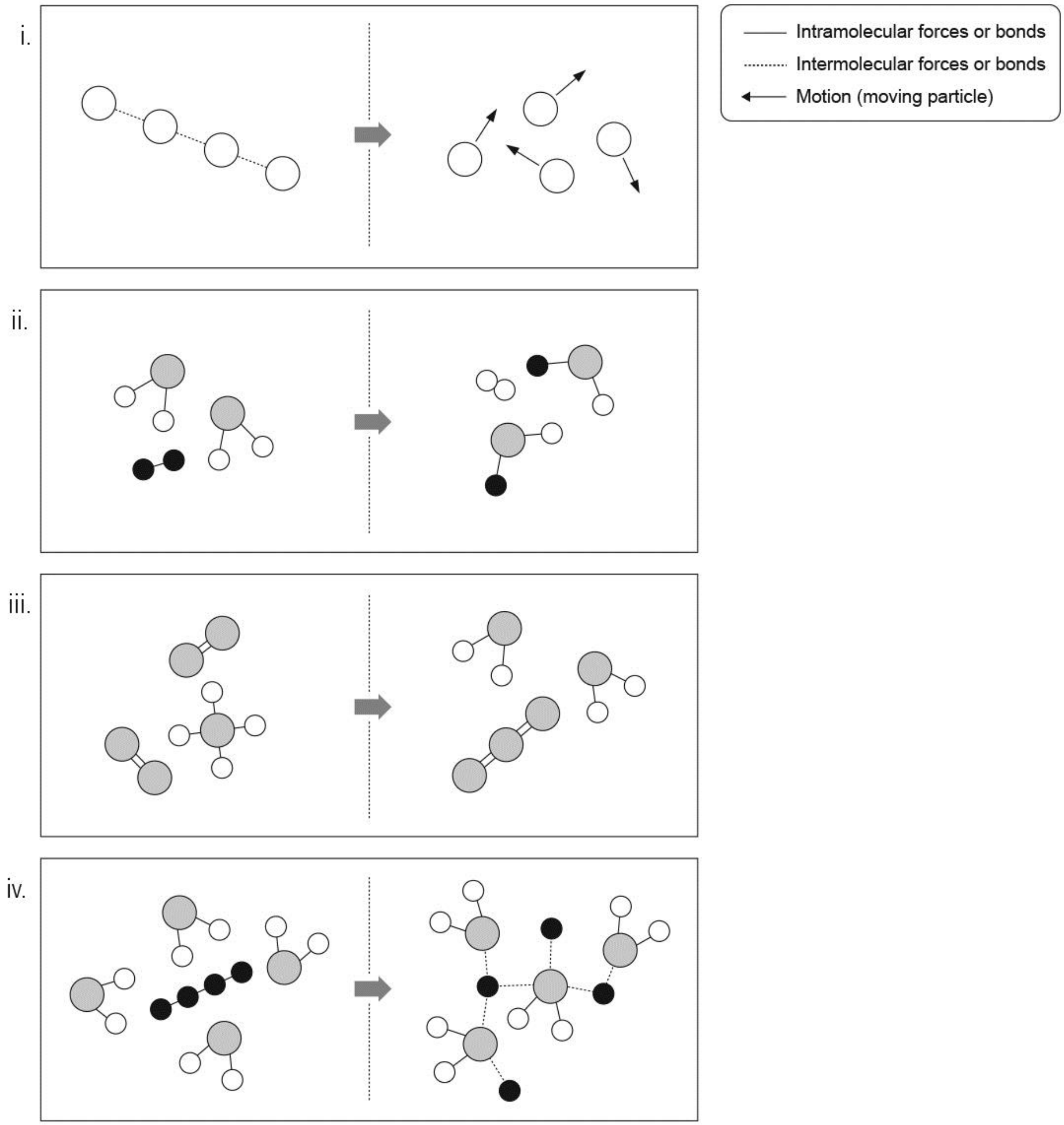
3. In this lab you also use a conductivity sensor. Consider the following particulate-level representations. Label the beakers as “Low conductivity”, “Medium conductivity”, or “High conductivity”. Explain your reasoning.



4. Finally, in this lab you use a pressure sensor. Consider the following particulate-level representations. Label the tubes as “High pressure” or “Low pressure”. Explain your reasoning.



5. Analyze the following particulate-level representations of different processes.



a. Which representations above show a change in both intramolecular bonds and intermolecular forces?

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b. Which representations above show a change in just intramolecular bonds? Justify your answer.

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c. Which representations above show a change in just intermolecular forces? Justify your answer.

MODEL 1

Building Model 1 – Is it a Chemical Change?

1. Obtain 6 clean 100-mL beakers and label them “A”, “B”, “C”, “D”, “AB”, and “CD”.

2. Pour 100 mL of Unknown 1A into Beaker A.

3. Pour 100 mL of Unknown 1B into Beaker B.

4. Pour 100 mL of Unknown 1C into Beaker C.

5. Pour 100 mL of Unknown 1D into Beaker D.

6. Combine 50 mL of Unknown 1A from Beaker A and 50 mL of Unknown 1B from Beaker B into Beaker AB. Note any visible changes that occur.

7. Combine 50 mL of Unknown 1C from Beaker C and 50 mL of Unknown 1D from Beaker D into Beaker CD. Note any visible changes that occur.

8. Observe Beakers AB and CD. Only one represents a chemical change. Speculate as to which beaker, AB or CD, represents a chemical change. Explain your reasoning.

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9. With your lab group, brainstorm how temperature, pH, and conductivity sensors could be used to determine which beaker underwent a chemical change.

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10. Start a new experiment on the data collection system.

11. Connect the pH sensor to the data collection system.

12. Calibrate the pH sensor.

13. Connect the temperature sensor to the data collection system.

14. Connect the conductivity sensor to the data collection system.

15. Display a digital readout of temperature, pH, and conductivity on the data collection system.

16. Empty Beakers AB and CD and rinse them thoroughly with distilled water.

17. Record observations of color, temperature, pH, and conductivity of the reactant beakers (A–D) by inserting the sensors into each beaker. Rinse the sensors between measurements with distilled water from a wash bottle. Record the data in the Model 1 Data Table.

18. Use the remaining solutions in Beakers A–D to repeat the reactions carried out above by combining the solutions in Beakers A and B and making measurements, and then combining the solutions in Beakers C and D and making measurements. Record observations of color, temperature, pH, and conductivity for both product Beakers AB and CD immediately after the reactants are mixed by inserting the sensors into each beaker. Rinse the sensors between measurements with distilled water. Record the data in the Model 1 Data Table.

Model 1 – Is it a Chemical Change?

Table 1: Model 1 Data Table—Determining a chemical change

Reactant Beaker	Color	pH	Temperature (ºC)	Conductivity (Low/Med/High)
A				
B				
AB				
C				
D				
CD				

For conductivity:
- Low: Less than 100 µS/cm
- Med: Between 100 µS/cm and 1000 µS/cm
- High: Greater than 1000 µS/cm

Analyzing Model 1 – Is it a Chemical Change?

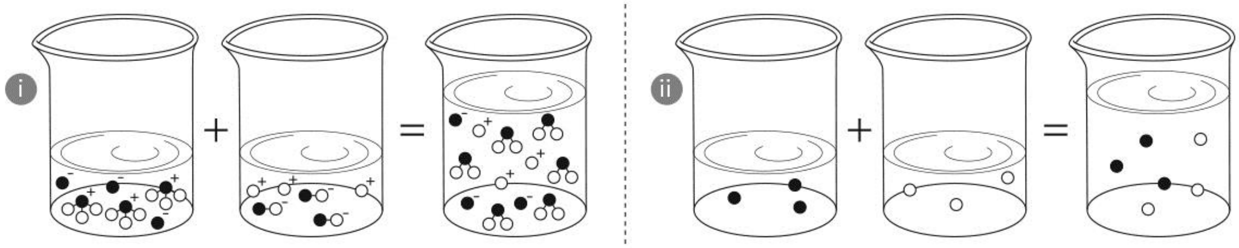
19. Which reaction, the one in Beaker AB or the one in Beaker CD, showed a greater change in temperature, conductivity, and pH?

20. When a large change in temperature is observed during a reaction, what might be occurring on the molecular level in the beaker?

21. When a large change in conductivity is observed during a reaction, what might be occurring on the molecular level in the beaker?

22. When a large change in pH is observed during a reaction, what might be occurring on the molecular level in the beaker?

23. Analyze the particulate-level representations below and answer the following questions.



a. Which set of particulate-level representations matches the data for mixing the solution in Beaker A with the solution in Beaker B to produce the products in Beaker AB? Explain your reasoning based on the sensor data.

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b. Which set of particulate-level representations matches the data for mixing the solution in Beaker C with the solution in Beaker D to produce the products in Beaker CD? Explain your reasoning based on the sensor data.

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24. A change in color can be a clue that chemical change is occurring. Was that the case in Model 1? Justify your answer with data from Model 1.

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25. Based on the particulate-level representations and sensor data collected, put a check by all the traits of a chemical change.

_______ a. Substance(s) remain unchanged.

_______ b. Atoms within molecules and compounds rearrange.

_______ c. Chemical properties of products are different than reactant properties.

_______ d. Chemical properties of products remain the same as reactant properties.

_______ e. Bonds are made or broken.

26. With your lab group, create a one-sentence definition of a chemical change.

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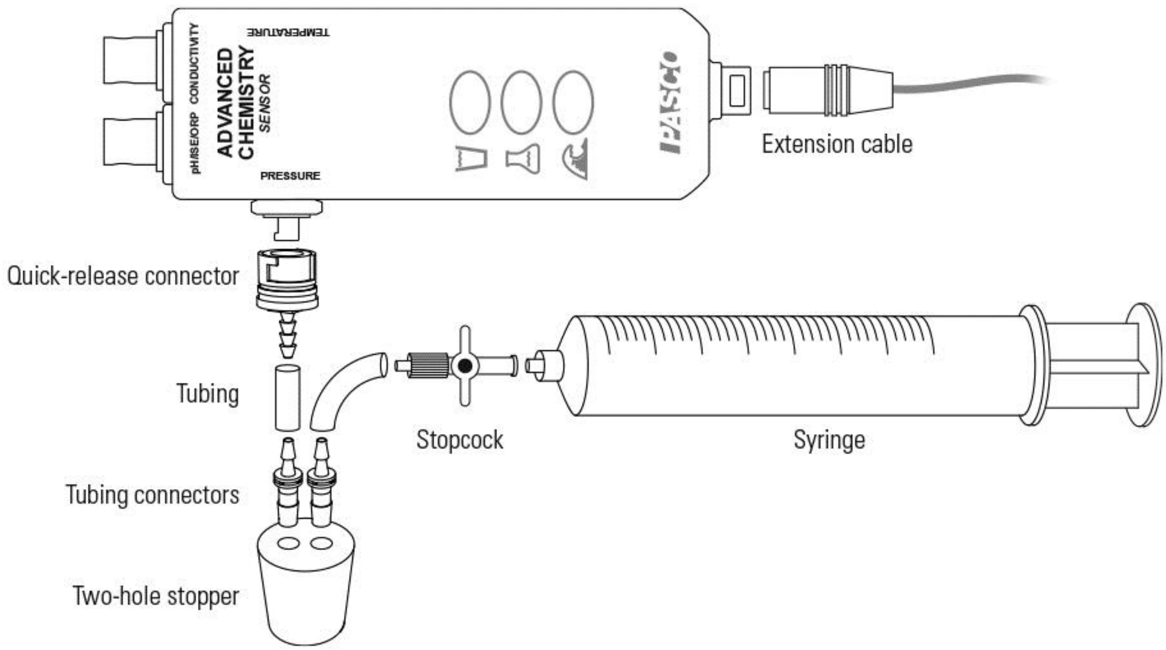
MODEL 2

Building Model 2 – Chemical versus Physical Change

1. Start a new experiment on the data collection system.

2. Connect the absolute pressure sensor to the data collection system using a sensor extension cable.

3. Connect the quick-release connector to the stopper using the tubing connector and the 1- to 2-cm piece of tubing by following the steps below. Use the picture as a guide.



   a. Insert the thicker end of one of the tubing connectors into the hole in the stopper. If this is difficult, add a drop of glycerin.

   b. Connect a 1- to 2-cm piece of tubing to the other, thinner end of the tubing connector.

   c. Insert the barbed end of the quick-release connector into the open end of the 1- to 2-cm piece of tubing. If this is difficult, add a drop of glycerin.

4. Insert the quick-release connector into the port of the absolute pressure sensor and then turn the connector clockwise until the fitting "clicks" onto the sensor (about one-eighth turn).

5. Display a pressure versus time graph on the data collection system.

6. Obtain two test tubes. Label them "A" and "B". Place them into a test tube rack.

7. Connect the syringe to the stopper as shown in the diagram and insert the stopper into Test Tube A. Start collecting data.

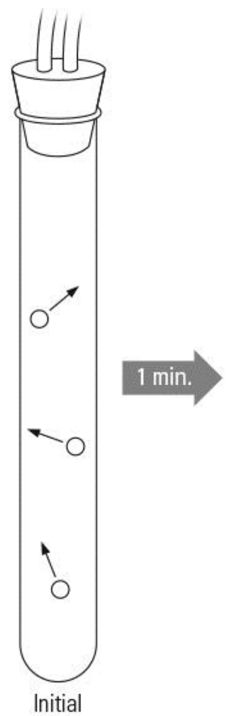
8. Using the syringe, obtain a 2 mL sample of Unknown 2A. Open the stopcock, quickly inject the sample, and pull the plunger back to the 2-mL mark.

9. Observe the change in pressure. Record if the pressure increased, decreased, or stayed the same over a 1-minute time interval in the Model 2 Data Table. Note any visible gas formation.

10. Remove the stopper and return the test tube to the test tube rack. Stop collecting data on the data collection system.

11. In the procedure just performed, you removed 2 mL of gas (mostly air) from the test tube after introducing the liquid. Explain why that step was necessary in order to keep the initial gas pressure constant.

The introduction of 2 mL of liquid reduces the volume occupied by gas in the test tube and increases the pressure. To keep the initial gas pressure constant, a volume of gas equal to that of the introduced liquid needed to be removed.



❷ 12. Using the particulate-level representations provided in the Getting Your Brain in Gear questions as a guide, draw gas molecules in the "Final" test tube to represent the pressure change you observed.

❷ 13. Explain how the pressure data collected helped you determine what happened in Test Tube A.

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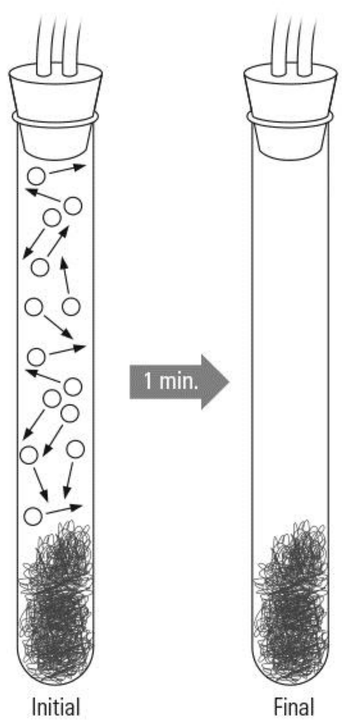
14. Take Test Tube B and, with tongs, fill the test tube one quarter full of Unknown 2B. Dry it with a paper towel and immediately place it inside Test Tube B. Be careful not to compress the unknown.

15. Remove the syringe and turn the stopcock to the closed position. Insert the stopper connected to the pressure sensor into the test tube and immediately start collecting data.

16. Observe the change in pressure. Record if the pressure increased, decreased, or stayed the same over a 10-minute time interval in Model 2. Note any visible gas formation and color change.

17. Stop collecting data on the data collection system. Remove the stopper and return the test tube to the test tube rack.



❷ 18. Using the particulate-level representations provided in the Getting Your Brain in Gear questions as a guide, draw gas molecules in the "Final" test tube to represent the pressure change you observed.

❷ 19. Explain how the pressure data collected helped you determine what happened in Test Tube B.

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20. Dispose of the unknowns in the proper waste containers. Clean the beakers and test tubes with soapy water.

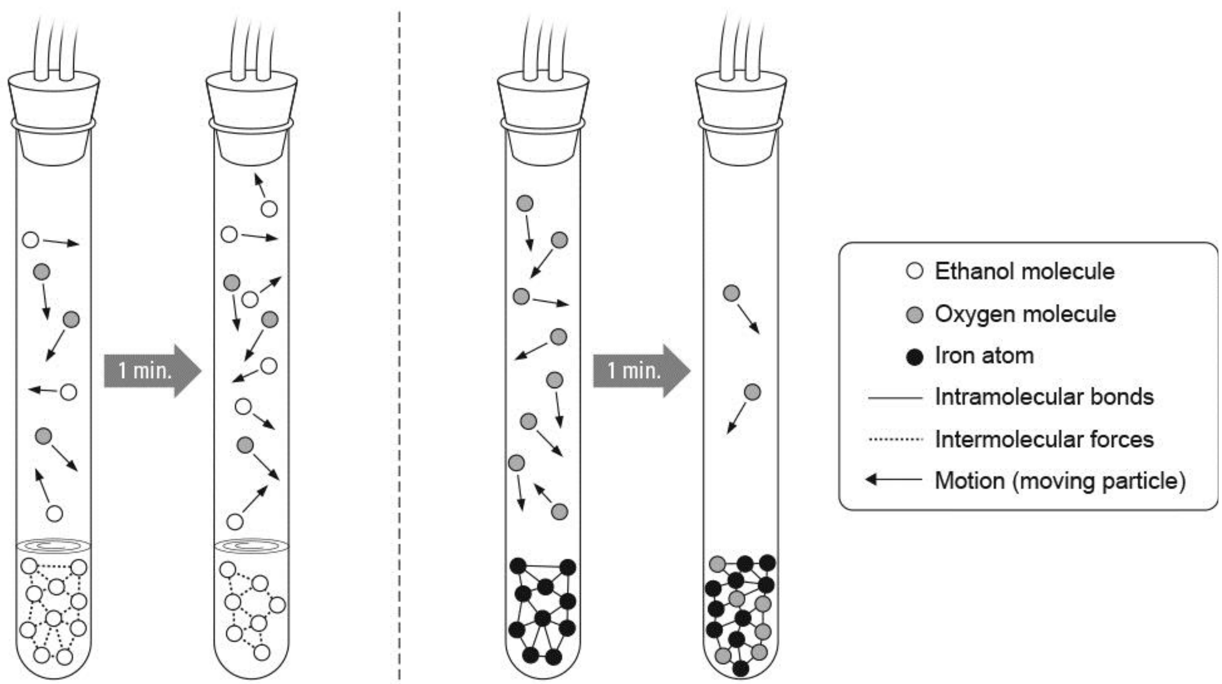
Model 2 – Chemical versus Physical Change

Table 2: Model 2 Data Table—Determining a chemical or physical change

Test Tube	Gas Visible?	Pressure Change (Increase/Decrease/Same)	Changes to Overall Appearance of Substances
A			
B			

Analyzing Model 2 – Chemical versus Physical Change

21. One of the changes observed in Model 2 was a chemical change and the other was a physical change. Use the particulate-level representations below and your data to answer the following questions.



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a. Label each diagram as representing either Test Tube A or Test Tube B.

b. Use the chemical change definition your group developed for Model 1 to identify which test tube, A or B, contained the chemical change. Explain why it is a chemical change.

22. An increase or decrease in pressure cannot, by itself, be used to differentiate between a physical or chemical change, but it does provide insight to what is happening with the substances.

    a. Explain how the pressure sensor was important in understanding what is happening inside the two different test tubes?

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    b. What other data helped you determine if a physical or chemical change occurred in the two test tubes?

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23. Consider the following statements and label them as representative of a chemical or physical change.

    ______________ a. Forming or breaking intermolecular forces

    ______________ b. Forming or breaking intramolecular forces or bonds

24. Revisit the particulate-level representations in question #5 of Getting Your Brain in Gear.

    a. Which representations are chemical changes?

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    b. Which representations are physical changes?

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25. In discussing the results of the reaction in Test Tube B, a student states "The stopper must be leaking, causing a drop in pressure." Explain why a drop in pressure cannot possibly result from a leak in the stopper in this situation.

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26. List at least two variables in the Test Tube B reaction that could be studied to determine how they might affect the magnitude of the pressure drop during the reaction.

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MODEL 3

Building Model 3 – Ambiguous changes

1. Carry out the reaction your teacher assigns your group.
2. Which change will your lab group complete?

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3. Predict what will change in terms of pH, temperature, and conductivity.

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4. Predict whether the change will be a chemical or physical change.

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5. Obtain a clean and dry 100-mL beaker.
6. Start a new experiment on the data collection system.
7. Connect the pH, conductivity, and temperature sensors.
8. Set up the screen to display temperature, pH, and conductivity.
9. Pour 50 mL of distilled water into the beaker. Record the initial pH, temperature, and conductivity in the Model 3 Data Table.
10. Add a small *pea sized* sample (about 0.5 g) of the other reactant to the beaker. Stir with the stirring rod.
11. Use the sensors to measure the final pH, temperature, and conductivity of the contents of the beaker immediately after the reactants are mixed. Record these in the Model 3 Data Table.
12. When all lab groups are finished with data collection, share data to complete the Model 3 Data Table.
13. Dispose of the contents of the beakers in the proper waste containers. Clean the beakers and test tubes with soapy water. Rinse the sensors with distilled water and properly disconnect them.

Model 3 – Ambiguous changes

Table 3: Model 3 Data Table—Determining the type of change

Reactants	Observations	Condition	pH	Temp (°C)	Conductivity (Low/Med/High)
$C_{12}H_{22}O_{11}$ + H_2O		Initial			
		Final			
NaCl + H_2O		Initial			
		Final			
$NaCH_3COO$ + H_2O		Initial			
		Final			
Ca + H_2O		Initial			
		Final			
NH_4NO_3 + H_2O		Initial			
		Final			

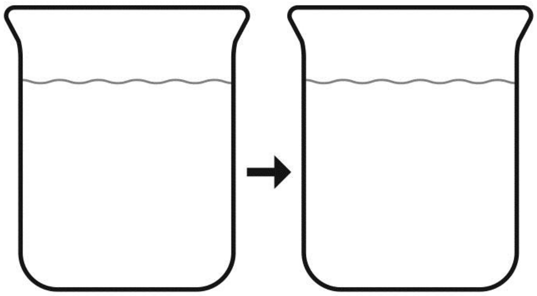
For conductivity:

Low: Less than 100 µS/cm
Med: Between 100 µS/cm and 1000 µS/cm
High: Greater than 1000 µS/cm

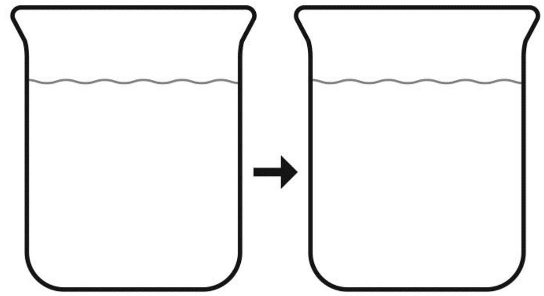
Analyzing Model 3 – Ambiguous changes

14. For the change that you observed, draw a particulate-level representation of the reaction that helps explain the data you collected with the sensors. Explain how the particulate-level representation is consistent with your data.

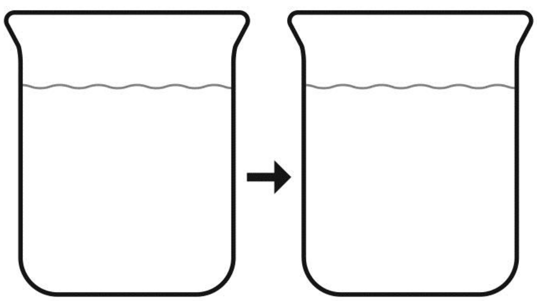
$C_{12}H_{22}O_{11}$ + H_2O



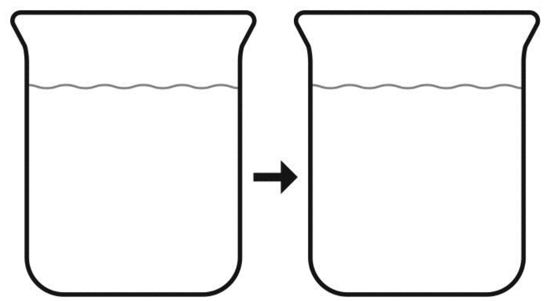
NaCl + H_2O



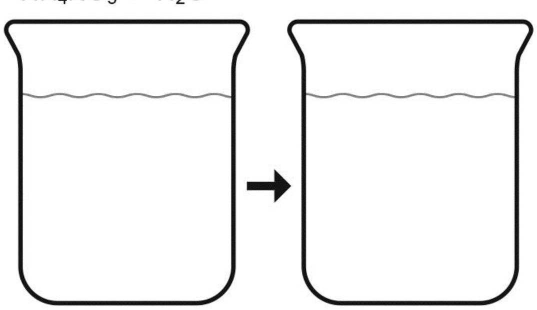
$NaCH_3COO$ + H_2O



Ca + H_2O



NH_4NO_3 + H_2O



15. Determine if each change is a chemical, physical, or ambiguous change. Support your answer with evidence from Model 3. Specify whether intramolecular or intermolecular bonds were affected. Was your prediction correct?

16. Two students were having a disagreement about whether $NaNO_3$ mixed with water results in a physical or chemical change. Student A claims it is a physical change because no new substance is formed and upon evaporation of the water, $NaNO_3$ could be recovered since only intermolecular forces change during dissolution. Student B claims it is a chemical change because the ionic bonds in $NaNO_3$, which are intramolecular, are broken by the water. This forms new ions, Na^+ and NO_3^-, that affect conductivity. What would your group tell Students A and B?

Connecting to Theory

When a process is classified as a chemical change, intramolecular interactions change, producing a new, chemically distinct substance due to the rearrangement of atoms. When a process is classified as a physical change, intermolecular interactions change. No new substances are produced. Atoms within the original molecules do not rearrange. Some processes can be labeled ambiguous changes when both intramolecular and intermolecular interactions change during the process.

Applying Your Knowledge

1. Reflecting on the entire lab, is identifying an unknown change as physical or chemical straightforward? Write a paragraph explaining your thoughts using data collected from this lab.

2. Scientific sensors can be used to understand what is happening on a scale far too small for humans to directly observe. Reflect on your use of technology during this lab. Write a paragraph on how technology can be used to visualize processes that cannot be directly observed. Use external resources to find examples of sensors not used in this lab.