Read Me: Copies of Posters and Worksheets for Systems and Scale

Here are the items that we will need printed for the Systems and Scale unit.

Item and file location	***Printing instructions***	***Number to Print***
Blank worksheets and handouts: Pages 2-19 of this file	Front only, 3-hole, black & white ((BW)	1 per student
Worksheets with comments: Pages 20-39 of this file	Back/back, BW, 3-hole	1 for teacher reference
Cards for sorting: *S&SCards.docx*	Color on white card stock	1 set per student group of 4, reusable
3QuestionsPoster.pptx	11x17, BW	1 to post on wall
ProcessToolPoster.pptx	24x36, BW	1 to post on wall
S&SPosters.pptx, pages 1, 3	11x17, BW	1 to post on wall
S&SPosters.pptx, page 2	11x17, color	1 per group of 4 students, reusable
S&SPosters.pptx, pages 4, 5, 8	11x17, BW	1 per class, consumable
S&SPosters.pptx, page 6	11x17, BW	1 per pair of students, reusable

Table of Contents

Teacher ________________Grade____ Period ____ Date _________Your initials ___ ___ ___

Systems and Scale Unit Pre- and Post-test **Lesson 1, Activity 1**

1. Answer these questions about what happens inside the flame of a kerosene lamp (kerosene is $C_{12}H_{26}$).

Do you think that **materials** (solids, liquids, or gases) are going into the flame? (circle one answer below) Yes No I'm not sure	Do you think that **energy** is going into the flame? (circle one answer below) Yes No I'm not sure
What materials do you think are going into the flame?	What forms of energy do you think are going into the flame?
Do you think that **materials** (solids, liquids, or gases) are coming out of the flame? (circle one answer) Yes No I'm not sure	Do you think that **energy** is coming out of the flame? (circle one answer below) Yes No I'm not sure
What materials do you think are coming out of the flame?	What forms of energy do you think are coming out of the flame?
How do you think that **materials** are changing inside the flame?	How do you think that **energy** is changing inside the flame?
What are you **not sure about** in your answers? Explain what you need to know to answer these questions better.	

2.A scientist started sorting materials into two groups, with these materials:

Group A: *Gasoline, alcohol, wood* ***Group B:*** *Sand, water, steel, carbon dioxide*

a. Which group would you put these materials in?

Salt	Group A	Group B
Sugar	Group A	Group B
Pork	Group A	Group B
Soil minerals that help plants grow	Group A	Group B
Leaves of a living tree	Group A	Group B

b. Explain how you decided. How are the materials in Group A different from the materials in Group B?

c. Is there a different way of grouping the materials that makes more sense to you?   Yes   No

d. Explain your answer. How would you group the materials differently, or why do you like these groups?

3. When alcohol burns, the alcohol loses weight. What happened to the **matter** that used to be in the alcohol?

a. Which of the following statements is true? Circle the correct answer.

ALL of the matter is still somewhere in the environment, OR
SOME of the matter was consumed by the flame and no longer exists.

b. Circle the best choice to answers the questions about possible places where the matter in the alcohol might go.

How much of the matter in the alcohol goes into the AIR?	All or most	Some	None
How much of the matter in the alcohol turns into HEAT AND LIGHT ENERGY?	All or most	Some	None
How much of the matter in the alcohol IS BURNED UP AND DISAPPEARS?	All or most	Some	None
How much of the matter in the alcohol goes into WATER VAPOR?	All or most	Some	None

c. Explain your choices. What happens to the matter in alcohol as it burns?

d. Does the air change when alcohol burns? Yes   No

e. If you answered "yes" explain how the air changes when alcohol burns.

4. Answer these true-false questions:

True	False	Carbon is a kind of atom.
True	False	Carbon is a kind of molecule.
True	False	There is carbon in pure air.
True	False	There is carbon in pure water.
True	False	There is carbon in alcohol.
True	False	There is carbon in wood
True	False	There is carbon in our muscles.

Name ______________________________ Teacher ________________ Date __________

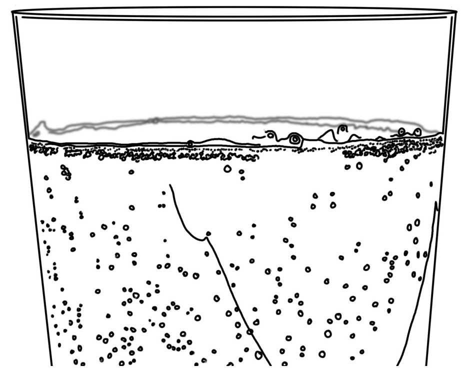
Atoms and Molecules Quiz

Lesson 2, Activity 3

You have studied three important facts about atoms:

1. Atoms last forever.
2. Atoms make up the mass of all materials.
3. Atoms are bonded to other atoms in molecules.

Use these facts and what you have learned about Powers of Ten to answer these questions.



1. These questions are about a glass of soda water that is fizzing.
   a. Do you think that the **oxygen atoms** in the water will still exist as oxygen atoms a million years from now? (Circle your answer)

Yes	No	Not sure

   b. Do you think that the **water molecules** will still exist as water molecules a million years from now? (Circle your answer)

Yes	No	Not sure

   c. Explain your answer. Use the facts about atoms if they are helpful

2. For each material, decide whether it a kind of atom, a kind of molecule, or both.

Material	***Circle the correct description***		
Water….	…is a kind of atom	…is a kind of molecule	…is both a kind of atom and a kind of molecule
Carbon…	…is a kind of atom	…is a kind of molecule	…is both a kind of atom and a kind of molecule
Nitrogen….	…is a kind of atom	…is a kind of molecule	…is both a kind of atom and a kind of molecule
Carbon dioxide….	…is a kind of atom	…is a kind of molecule	…is both a kind of atom and a kind of molecule

3. Explain what the difference is between an oxygen **atom** and an oxygen **molecule.**

4. Someone said that if a boy gains weight, then he MUST have added more atoms to his body. Do you agree?

Yes	No

   Explain your reasoning. What is the connection between adding weight and adding atoms?

Name ______________________________ Teacher ________________ Date __________

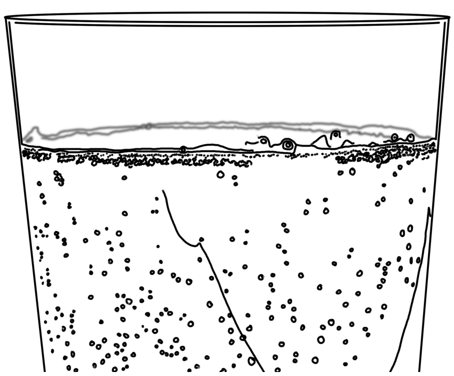
Initial Predictions and Explanations Worksheet

Lesson 3, Activity 2

You will be doing an investigation of soda water fizzing. Here are the tools that you will have:

- A balance that weighs materials accurately to 0.01 grams
- An air-tight (or mostly air-tight) container
- Bromothymol blue (BTB) solution to detect CO_2 in the air inside the container
- Soda water in a shallow glass Petri dish

Make predictions that will help you answer the three questions.

Predictions about mass changes: What are your predictions about objects or materials that will gain or lose mass? What will gain mass? What will lose mass?	**Predictions about changes in BTB:** Do you think that BTB will change color if it is in a closed container with fizzing soda water? YES NO What color change do you predict?
The Movement Question: Explaining your predictions about mass changes: Draw your ideas about how atoms are moving on the picture below.  Where are atoms moving from? Where are atoms going to?	**The Carbon Question: Explaining your predictions about BTB color changes:** What do you think is happening to molecules that have carbon atoms in them?

Name ______________________________ Teacher ________________ Date __________

Soda water Fizzing Observations and Conclusions Worksheet

Lesson 3, Activity 3

A. Steps in the investigation: Check the box as you complete each step.

1. ☐ Add soda water to an open petri dish.
2. ☐ Turn on a digital scale so that it reads "0" g. Place the petri dish with soda water on the scale. Record the masses in the "Measurements during the Investigation" section below.
3. ☐ Place the petri dish into an air-tight container or an inverted clear plastic container.
4. ☐ Fill a petri dish with fresh BTB. On the worksheet, fill in your observation of the color of the BTB.
5. ☐ Place the petri dish with BTB next to the petri dish with soda water into one container and close the container.
6. ☐ After 20 minutes, check the color of the BTB. You may choose to wait longer to observe a final BTB color.
7. ☐ For your last observation of BTB color, open the lid of the container. Record the color of the BTB. Remove the petri dish with the soda water. Weigh the soda water and record the observation on your worksheet.

B. Measurements during the investigation. Record your measurements on the table below.

Measurements Before	***Measurements After***
Mass of Petri dish with soda water before Mass: ________________ grams	**Mass of Petri dish with soda water after** Mass: ________________ grams Change in mass: ________________ grams
Color of BTB before Time: ______________________ Color of BTB: __________________________	**Changes in color of BTB** Time: _______________ Color: ___________ Time: _______________ Color: ___________ Change in color: ________________________

C. Results for the whole class: Make notes about how the measurements and observations of other groups in the class compared to yours.

Changes in mass of Petri dish with soda water
Changes in color of BTB

Name ______________________________ Teacher ________________ Date __________

Soda Water Molecular Models Worksheet

Lesson 3, Activity 4

A. Using molecular models to show the chemical change. "Carbonated water" gets its name from a weak acid called carbonic acid (H_2CO_3). That's what gives soda its sharp "fizzy" taste. Use the molecular models to figure out how carbonic acid can break up into molecules of water and carbon dioxide when soda water loses its fizz

1. ☐ Make a model of a carbonic acid molecule (H_2CO_3) and put it on the *reactant* side of the Process Tool for Molecular Models poster.
2. ☐ Show how a carbonic acid molecule can come apart, then the atoms can recombine into carbon dioxide (CO_2) and water (H_2O). Make these molecules from your carbonic acid molecule and move them to the *product* side of the Process Tool for Molecular Models poster.

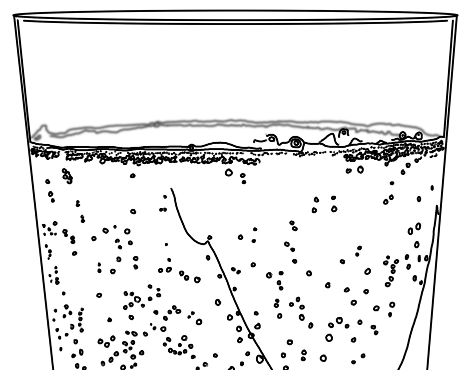
B. Atoms Last Forever!! Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change?

	Matter		
	How many carbon atoms	How many oxygen atoms	How many hydrogen atoms
Began with…			
Carbonic acid			
End with…			
Carbon Dioxide			
Water			
Total number of atoms in products			

C. Writing the chemical equation. Use the molecular formulas (H_2CO_3, CO_2, H_2O) and the yield sign (→) to write a balanced chemical equation for the reaction:

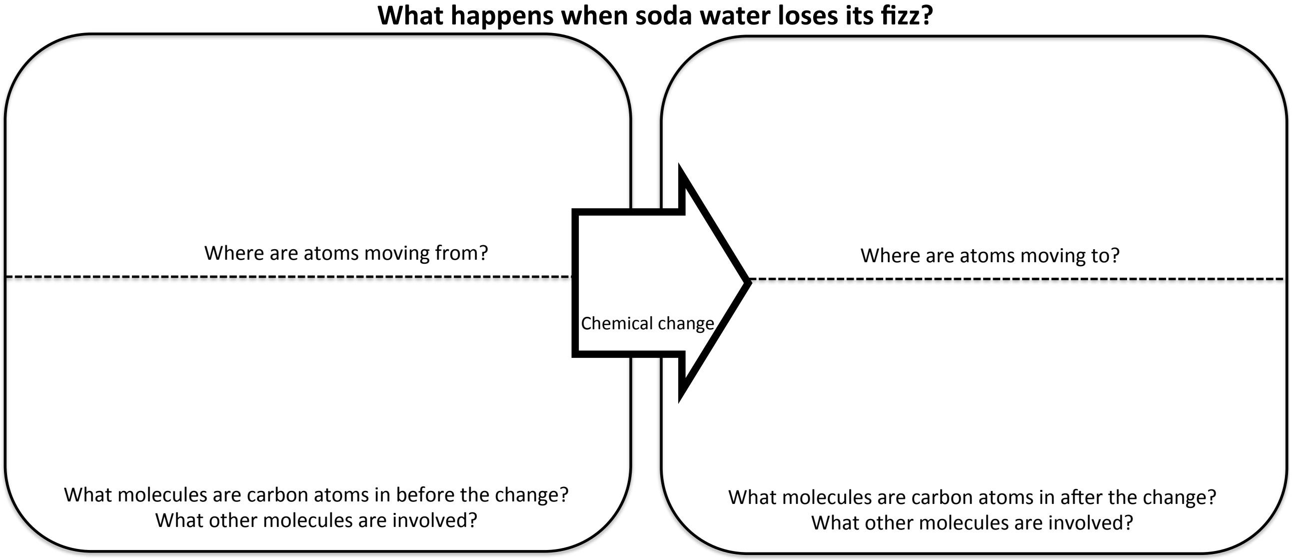
D. Revising your answers to the Movement Question and the Carbon Question. Try revising your answers to the two questions.

1. The Movement Question: Where are atoms moving?
2. The Carbon Question: What is happening to carbon atoms?

1. Bubbles: What molecules are in the bubbles of fizzing soda water? **2. Changes in mass:** a. What materials *lost mass* due to the movement of atoms? b. What materials *gained mass* due to the movement of atoms?	**Drawing motions of atoms:** Draw arrows to show how atoms move into, through, and out of the soda water. 

Revise your answers to these questions on the Process Tool below.

What happens when soda water loses its fizz?



Remember: **Atoms last foreve**r (so you can rearrange atoms into new molecules, but can't add or subtract atoms)

Name ______________________________ Teacher ________________ Date __________

Initial Predictions and Explanations Worksheet

Lesson 4, Activity 1

You will be doing an investigation of ethanol burning. Here are the tools that you will have:

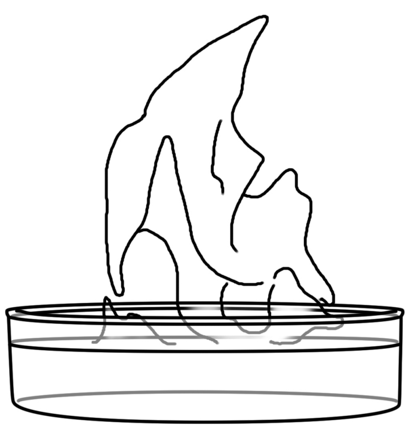
- A balance that weighs materials accurately to 0.01 grams
- An air-tight (or mostly air-tight) container
- Bromothymol blue (BTB) solution to detect CO_2 in the air inside the container
- Ethanol that you can burn in a shallow glass Petri dish

Make predictions that will help you answer the three questions.

<table>
<tr>
<td>Predictions about mass changes: What are your predictions about objects or materials that will gain or lose mass?
What will gain mass?

What will lose mass?</td>
<td>Predictions about changes in BTB: Do you think that BTB will change color if it is in a closed container with burning ethanol?

YES NO

What color change do you predict?</td>
</tr>
<tr>
<td rowspan="2">The Movement Question: Explaining your predictions about mass changes: Draw your ideas about how atoms are moving on the picture below.

Where are atoms moving from?

Where are atoms going to?</td>
<td>The Carbon Question: Explaining your predictions about BTB color changes: What do you think is happening to molecules that have carbon atoms in them?</td>
</tr>
<tr>
<td>The Energy Question: Explaining changes in forms of energy: How do you think that energy is changing from one form to another?</td>
</tr>
</table>

Name ______________________________ Teacher ________________ Date __________

Burning Ethanol Observations and Conclusions Worksheet

Lesson 4, Activity 2

A. Procedures to follow

1. ☐ Add ethanol to an open glass petri dish.
2. ☐ Turn on a digital scale so that it reads "0" g. Place the petri dish with ethanol on the scale. Record the mass of ethanol in the "Measurements during the Investigation" worksheet.
3. ☐ Fill a petri dish with fresh BTB. On the worksheet, fill in your observation of the color of the BTB.
4. ☐ Place the petri dish with BTB next to the petri dish with ethanol so that the large container lined with aluminum foil fits on top of the two dishes.
5. ☐ Light the ethanol with the lighter and then immediately put the container lined with aluminum foil on top of both the glass petri dish with burning ethanol and the petri dish of BTB. The flame will go out quickly inside the container.
6. ☐ Wait about 20 minutes before taking the lid off the container. Observe and record changes in the color of the BTB during the 20 minutes.
7. ☐ After 20 minutes, remove the ethanol from underneath the container. Place the petri dish on the digital scale and record the mass of the ethanol in the petri dish.
8. ☐ Fill in your observation of the color of the BTB after the experiment.

B. Measurements during the investigation. Record your measurements on the table below.

Measurements Before	***Measurements After***
Mass of Petri dish with ethanol before Time: ____________________ Mass: _______________ grams	**Mass of Petri dish with ethanol after** Time: ____________________ Mass: _______________ grams Change in mass: _______________ grams
Color of BTB before Time: ____________________ Color of BTB: ________________________	**Changes in color of BTB** Time: ______________ Color: __________ Time: ______________ Color: __________ Change in color: ______________________

C. Results for the whole class: Make notes about how the measurements and observations of other groups in the class compared to yours.

Changes in mass of Petri dish with ethanol   **Changes in color of BTB**

The Three Questions: Explaining Matter and Energy in Combustion and Life

Scientific explanations of processes include answers to three questions:

Question	Rules to Follow	Evidence to Look For
The Movement Question: Where are atoms moving? Where are atoms moving from? Where are atoms going to?	**Atoms last forever** in combustion and living systems All materials (solids, liquids, and gases) are made of atoms	When materials change mass, atoms are moving When materials move, atoms are moving
The Carbon Question: What is happening to carbon atoms? What molecules are carbon atoms in before the process? How are the atoms rearranged into new molecules?	Carbon atoms are bound to other atoms in molecules **Atoms can be rearranged to make new molecules**	The air has carbon atoms in CO_2 Organic materials are made of molecules with carbon atoms • Foods • Fuels • Living and dead plants and animals
The Energy Question: What is happening to chemical energy? What forms of energy are involved? How is energy changing from one form to another?	**Energy lasts forever** in combustion and living systems C-C and C-H bonds have more stored chemical energy than C-O and H-O bonds	We can observe indicators of different forms of energy • Organic materials with chemical energy • Light • Heat energy • Motion

Forms of Energy Cards

Chemical Energy	Light Energy
Heat Energy	Work/Energy of Motion

Name ______________________________ Teacher ________________ Date __________

Explaining What Happens When Ethanol Burns Worksheet

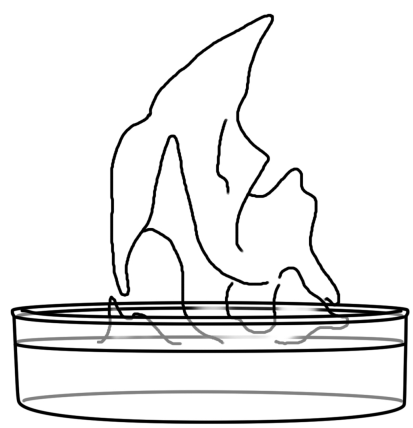
Lesson 4, Activity 3

Now let's explain in more detail what happens when ethanol burns. Here's how you will answer the questions:

1. The Movement Question: Where are atoms moving?
   a. You will watch the PowerPoint slides, "Zooming into a Flame."
   b. You will answer the questions below to show the important movements of atoms in a flame.
2. The Carbon Question: What is happening to carbon atoms?
   a. You will use molecular models to make molecules of ethanol and oxygen, then show how the atoms can be rearranged into carbon dioxide and water.
   b. You will write a chemical equation to show how the atoms are rearranged.
   c. You will use the Matter and Energy Process Tool to explain how carbon atoms in ethanol can become carbon atoms in carbon dioxide when ethanol burns.
3. The Energy Question: What is happening to chemical energy?
   a. You will use molecular models identify high-energy bonds (chemical energy) in the molecules involved in ethanol burning.
   b. You will use the Matter and Energy Process Tool to explain how the chemical energy in ethanol is changed into other forms of energy: motion, heat, and light.

A. Answering the movement question

Use the PowerPoint slides "Zooming into a Flame" to answer the questions below.

Bottom of the flame: What kinds of molecules do you see in the bottom of the flame? Where did those molecules come from? What atoms are those molecules made of?	**Drawing motions of atoms:** Draw arrows to show how atoms move into, through, and out of the flame. 
Top of the flame: What kinds of molecules do you see at the top of the flame? Which molecules are different from those at the bottom of the flame? Are the atoms at the top of the flame different from the atoms at the bottom of the flame?	

B. Using molecular models to show the chemical change. There are many different kinds of alcohol. The most common is ethanol: This is the kind of alcohol in alcoholic drinks and in biofuels. (The next time you get gasoline, check the pump to see if it says "10% ethanol.")

Ethanol is a good fuel because it has **chemical energy** stored in its high-energy bonds: C-C and C-H bonds. When ethanol burns, it reacts with oxygen (O_2) in the air to produce carbon dioxide (CO_2) and water (H_2O). Since carbon dioxide and water have only low-energy bonds (C-O and H-O), the chemical energy is released as heat and light. Use the molecular models to show how this happens

1. Work with your partner to make models of the reactant molecules: ethanol and oxygen and show how chemical energy is stored in the high-energy bonds of ethanol.
    a. ☐ Make models of an ethanol molecule (C_2H_5OH) and oxygen molecules (O_2, with a double bond). The air has lots of oxygen, so make a few more O_2 molecules than you will need—about 5. Put these molecules on the *reactant* side of the <u>Process Tool for Molecular Models</u> poster.
    b. ☐ Use twisty ties to represent chemical energy. Put a twisty tie around **each** high-energy bond (C-C and C-H bonds) in the ethanol molecule. Note how many energy units (twisty ties) there are in the ethanol molecule.
2. Show how the atoms of the reactant molecules can recombine into product molecules—carbon dioxide and water—and show how chemical energy is released when this happens.
    a. ☐ Take the ethanol and some of the oxygen molecules apart and recombine them into carbon dioxide (CO_2) and water (H_2O) molecules. Put these molecules on the *product* side of the <u>Process Tool for Molecular Models</u> poster. Some things to notice:
        i. How many oxygen molecules reacted with one ethanol molecule? _____
        ii. How many carbon dioxide molecules were produced? _____
        iii. How many water molecules were produced? _____
    b. ☐ Energy lasts forever, so move the twisty ties to the *product* side of the <u>Process Tool for Molecular Models</u> poster. Carbon dioxide and water have only low-energy bonds (C-O and H-O), so what forms does the chemical energy change into?

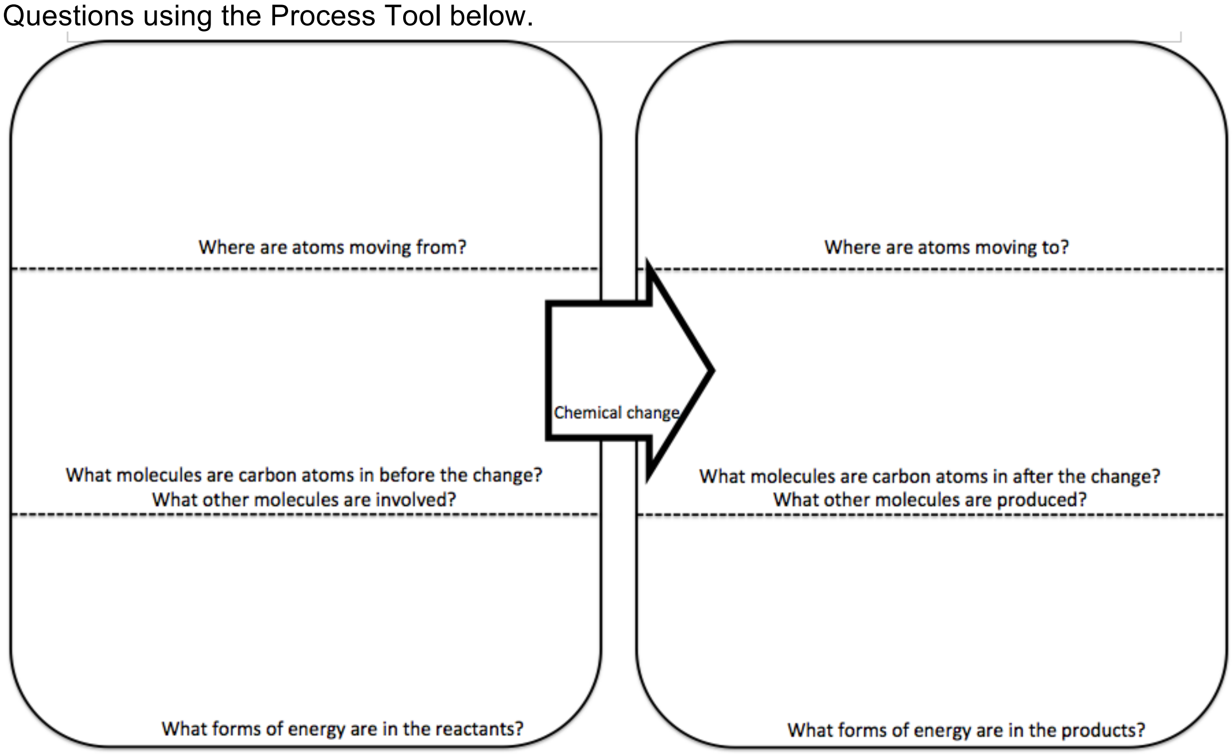
C. Atoms last forever!! Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change? Use the table below to account for all the atoms and bonds in your models.
Energy lasts forever! Write the type of energy for reactants and products in the chemical change.

	Matter			**Energy**	
	How many carbon atoms	How many oxygen atoms	How many hydrogen atoms	How many twisty ties?	What forms of energy?
Reactants					
Ethanol					
Oxygen					

	Matter			Energy	
Reactants totals					
Products					
Carbon Dioxide					
Water					
Products totals					

D. Writing the chemical equation. Use the molecular formulas (C_2H_5OH, O_2, CO_2, H_2O) and the yield sign (→) to write a balanced chemical equation for the reaction:

E. Revising your answers to the Three Questions. Try revising your answers to the Three Questions using the Process Tool below.



Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)

Name ________________________________ Teacher _________________ Date __________

Explaining What Happens When Methane Burns Worksheet

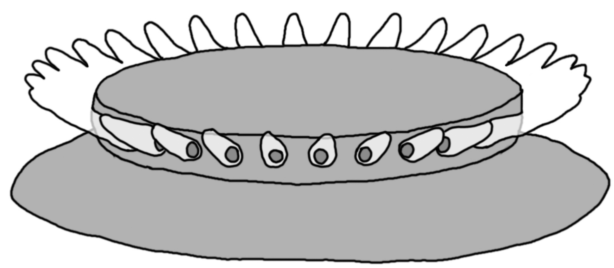
Lesson 5, Activity 1

Now let's explain what happens when another fuel burns: Methane or natural gas. Try answering the three questions for what happens when a gas stove burns methane (CH_4). Methane burns in the same way as ethanol burns: molecules of methane combine with oxygen to produce carbon dioxide and water.

To explain what happens when methane burns, you need to answer the three questions:

1. The Movement Question: Where are atoms moving?
2. The Carbon Question: What is happening to carbon atoms?
3. The Energy Question: What is happening to chemical energy?

A. Answering the movement question. Show how atoms are moving in the gas flame.

What kinds of molecules are coming into the bottom of the flame? What kinds of molecules are leaving the top of the flame.	**Drawing motions of atoms:** Draw arrows to show how atoms move into, through, and out of the flame. 

B. Using molecular models to show the chemical change. Use molecular models to show what happens when methane burns:

1. Work with your partner to make models of the reactant molecules: methane (CH_4) and oxygen (O_2, with a double bond). Put a twisty tie around **each** high-energy bond (C-C and C-H bonds) in the methane molecule. Put these molecules on the *reactant* side of the Process Tool for Molecular Models poster.
2. Show how the atoms of the reactant molecules can recombine into product molecules—carbon dioxide and water—and show how chemical energy is released when this happens. Take the ethanol and some of the oxygen molecules apart and recombine them into carbon dioxide (CO_2) and water (H_2O) molecules. Put these molecules on the *product* side of the Process Tool for Molecular Models poster. Notice how many of each type of molecule you have. Carbon dioxide and water have only low-energy bonds (C-O and H-O), so what forms does the chemical energy change into?

C. Atoms last forever! Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change? Use the table below to account for all the atoms and bonds in your models.

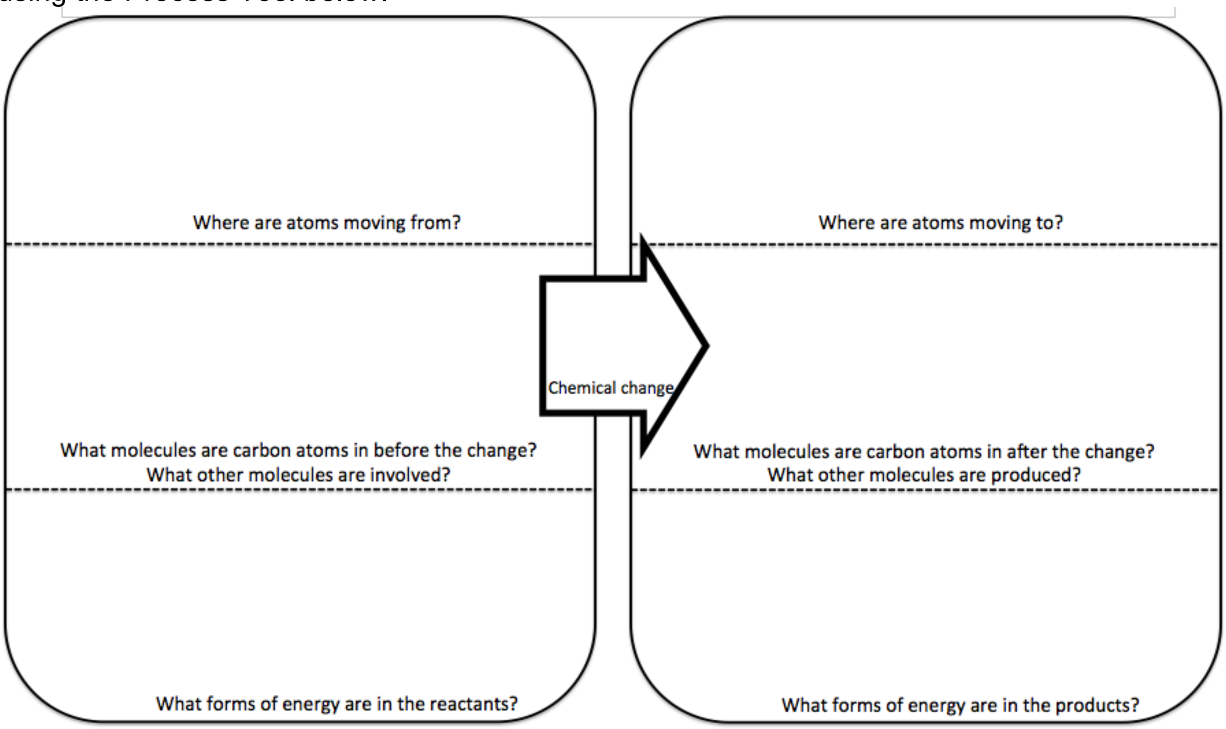
Energy lasts forever! Write the type of energy for reactants and products in the chemical change.

	Matter	Energy

	How many carbon atoms	How many oxygen atoms	How many hydrogen atoms	How many twisty ties?	What forms of energy?
Reactants					
Methane					
Oxygen					
Reactants totals					
Products					
Carbon Dioxide					
Water					
Products totals					

D. Writing the chemical equation. Use the molecular formulas (CH_4, O_2, CO_2, H_2O) and the yield sign (→) to write a balanced chemical equation for the reaction:

E. Using the Process Tool to answer the Three Questions. Answer the Three Questions using the Process Tool below.



Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)

Name ______________________________ Teacher ________________ Date __________

Is it Organic? Worksheet

Lesson 5, Activity 2

Use two different methods to sort the 12 materials on your materials cards into organic and inorganic materials.

A: Sorting based on properties you can see or the origins of materials. Sort the materials based on what you can see or feel or your knowledge of where they came from.

1. Organic materials. In this group you should include:

a. *Foods* or materials made from foods.
b. *Fuels* or materials made from fuels
c. *Bodies of living things* or materials made from the bodies of living things.

List the organic materials below.

2. Inorganic materials include materials that are not foods, fuels, or made from the bodies of living things. List the inorganic materials here.

B. Sorting based on bonds in molecules. Sort the materials based on the kinds of bonds they have in their molecules.

1. Organic materials. In this group you should include materials whose molecules have high-energy bonds: C-C and C-H. List the organic materials below.

2. Inorganic materials include materials whose molecules do not have C-C or C-H bonds. List the inorganic materials below.

C. Chemical energy. What is the difference in chemical energy between organic and inorganic materials?

D. Unknown liquid. How could you tell whether an unknown material—a clear liquid—will burn or not? What tests could you do or questions could you ask to predict whether it will burn?

Name ______________________________ Teacher ________________ Date __________

Other Examples of Combustion Worksheet

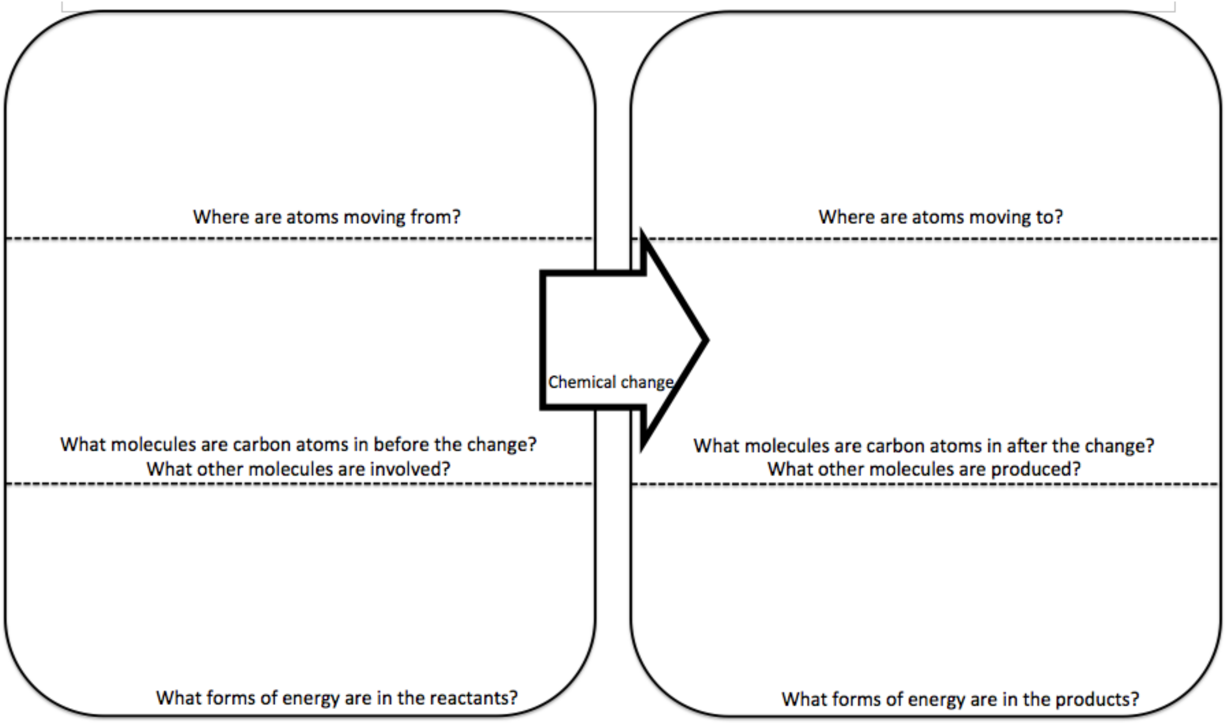
Lesson 5, Activity 3

Choosing examples. Choose two examples of other materials that burn from the list below:

- Methane (CH_4): Natural gas that is used for gas stoves and to heat homes
- Propane (C_3H_8): Used in tanks for gas grills
- Butane (C_4H_{10}): Used in cigarette lighters
- Octane (C_8H_{18}): One of the main components of gasoline
- A burning marshmallow: One of its main components is a sugar, glucose ($C_6H_{12}O_6$)
- A burning candle: Candle wax is a mixture of large hydrocarbon molecules such as pentacosane ($C_{25}H_{52}$).

A. First example: What example of combustion did you choose? ____________________

Using the Process Tool to answer the Three Questions. Answer the Three Questions using the Process Tool below.



Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)

CHECKING YOURSELF: Does you account follow the rules?

□ **Atoms last forever:** Do your answers to the questions explain how atoms can move or be rearranged into new molecules, but are not created or destroyed?

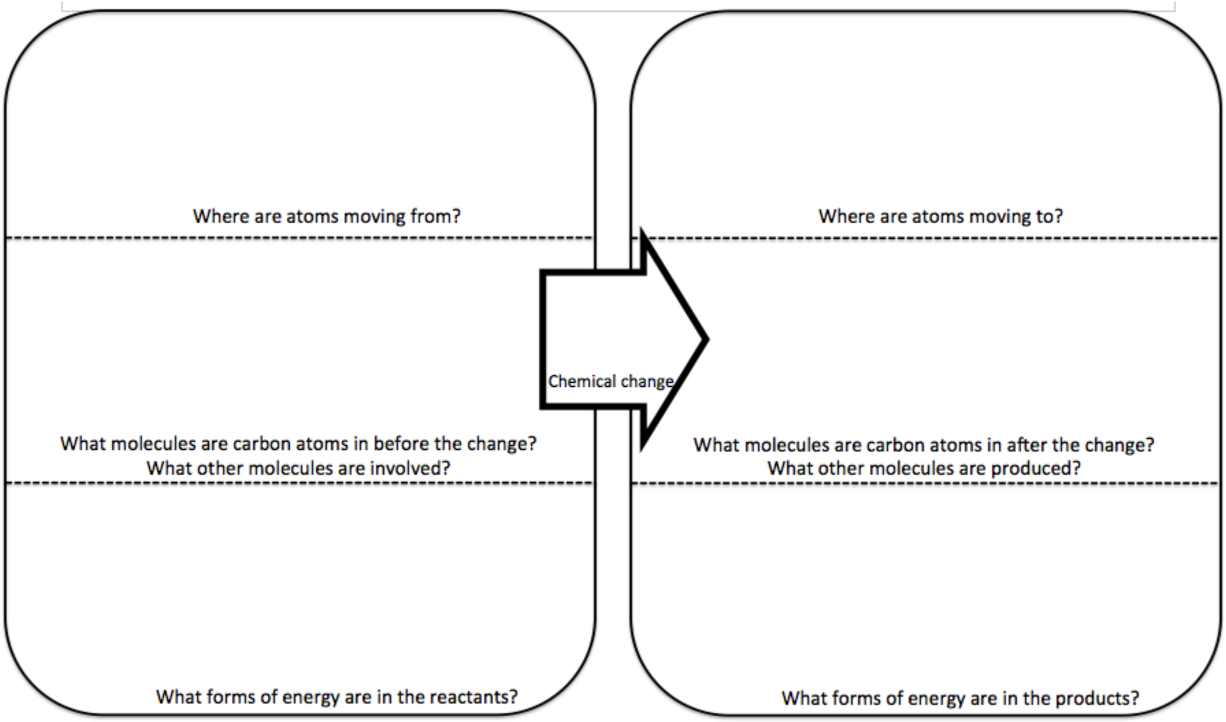
□ **Energy lasts forever:** Do your answers to the questions explain how energy changes from one form to another, but there is the same amount of energy after the process as before?

BONUS: Making molecular models. Make a molecular model of the material you chose and show how it can combine with oxygen to produce the products**.**

BONUS: Writing the chemical equation. Use the molecular formulas and the yield sign (→) to write a balanced chemical equation for the reaction:

B. Second example: What example of combustion did you choose? ______________________

Using the Process Tool to answer the Three Questions. Answer the Three Questions using the Process Tool below.



Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)

CHECKING YOURSELF: Does you account follow the rules?

□ **Atoms last forever:** Do your answers to the questions explain how atoms can move or be rearranged into new molecules, but are not created or destroyed?

□ **Energy lasts forever:** Do your answers to the questions explain how energy changes from one form to another, but there is the same amount of energy after the process as before?

BONUS: Making molecular models. Make a molecular model of the material you chose and show how it can combine with oxygen to produce the products.

BONUS: Writing the chemical equation. Use the molecular formulas and the yield sign (→) to write a balanced chemical equation for the reaction:

Comments on Tests and Worksheets

Assessing the Unit Pre-test

Lesson 1, Activity 1

We recommend that you NOT grade the pretest. Encourage your students to express their ideas, then look at their tests to assess what they understand about systems and scale.

Level 4 (correct) responses to the questions are in ***blue bold italics*** *below. There are also comments connecting the questions to unit activities in blue italics.*

1. Answer these questions about what happens inside the flame of a kerosene lamp (kerosene is $C_{12}H_{26}$)

Do you think that **materials** (solids, liquids, or gases) are going into the flame? (circle one answer below) ***Yes*** No I'm not sure	Do you think that **energy** is going into the flame? (circle one answer below) ***Yes*** No I'm not sure
What materials do you think are going into the flame? ***Air (or oxygen) and kerosene (or kerosene vapor) are going into the flame.*** *This assesses students' understanding of the Movement Question. Level 2 students may not list air or oxygen.*	What forms of energy do you think are going into the flame? ***Chemical energy in the kerosene is going into the flame.*** *Level 2 students may believe that the flame makes the energy. Level 2 and Level 3 students may not distinguish between kerosene (a material) and the chemical energy in kerosene.*
Do you think that **materials** (solids, liquids, or gases) are coming out of the flame? (circle one answer) ***Yes*** No I'm not sure	Do you think that **energy** is coming out of the flame? (circle one answer below) ***Yes*** No I'm not sure
What materials do you think are coming out of the flame? ***Carbon dioxide and water vapor (and smoke) are coming out of the flame.*** *Level 2 students may not identify any materials coming out of the flame. Level 3 students will not identify water vapor.*	What forms of energy do you think are coming out of the flame? ***Heat (thermal energy) and light energy are coming out of the flame.*** *Most students will probably answer this question correctly.*
How do you think that **materials** are changing inside the flame? ***Correct answers would include some representation of a chemical change. For example:*** • ***The atoms of kerosene and oxygen are being rearranged into CO_2 and H_2O.*** • ***A chemical reaction is changing the reactants into the products*** • ***A chemical equation.*** *Level 2 students are likely to*	How do you think that **energy** is changing inside the flame? ***Chemical energy is changed into heat and light.*** *Level 2 students may describe energy being produced rather than transformed. Level 3 students may describe matter-energy transformation (e.g., the kerosene is made into energy or produces energy.)*

	describe the fuel as being burned up or used up. Level 3 students may say that the kerosene is converted to energy.	
	What are you **not sure about** in your answers? Explain what you need to know to answer these questions better. *Look for a **sense of necessity** in the students' responses. If the students are trying to trace matter and energy but don't understand the details, they are well prepared to learn from this unit.*	

1. A scientist started sorting materials into two groups. Here are the first materials that she put into each group:
Group A: *Gasoline, alcohol, wood* ***Group B:*** *Sand, water, steel, carbon dioxide*

a. Which group would you put these materials in?

Salt		Group A	***Group B***
Sugar		***Group A***	Group B
Pork		***Group A***	Group B
Soil minerals that help plants grow		Group A	***Group B***
Leaves of a living tree	***Group A***	Group B	

b. Explain how you decided. How are the materials in Group A different from the materials in Group B?

Students could correctly distinguish the materials in several ways:
- ***Group A materials are organic; Group B materials are inorganic.***
- ***Group A materials have C-C and C-H bonds; Group B materials do not.***
- ***Group A materials have more chemical energy than Group B materials.***
- ***Group A materials have organic carbon; Group B materials do not.***

Most students probably will not use any of these explanations:
- *Level 2 students are likely to focus on how people make or use the materials, explaining their choices in terms of whether the materials are natural or made by humans, or how humans use them.*
- *Level 3 students are likely to focus on properties of the materials rather than how humans make and use them, but they will not be successful in using one of the practices to distinguish between types of materials.*

c. Is there a different way of grouping the materials that makes more sense to you? Yes ***NO****

d. Explain your answer. Why should we have three groups, or why do all the materials fit into two groups?

Level 4 students will recognize that all of the materials can be classified as organic or inorganic and could explain their decisions in several ways:
- ***All of the materials are either organic or inorganic.***
- ***All of the materials are made of molecule that have C-C and C-H bonds or do not.***

- ***All of the materials can be grouped according to how much chemical energy they have.***
- ***All of the materials have a place in the carbon cycle. (*NOTE: Students who say that salt does not have a place in the carbon cycle have reasonable Level 4 answers.)***

- *Most students will probably not use any of the explanations above, but you may encounter some of these responses from Level 2 and 3 students:*
- *Level 2 students are likely to explain their choices in terms of whether the materials are natural or made by humans, or how humans use them.*
- *Level 3 students are likely to focus on properties of the materials rather than how humans make and use them, but they will not be successful in using one of the practices to distinguish between types of materials.*

3. When alcohol burns, the alcohol loses weight. What happened to the **matter** that used to be in the alcohol?

a. Which of the following statements is true? Circle the correct answer.

ALL of the matter is still somewhere in the environment, OR
SOME of the matter was consumed by the flame and no longer exists.

b. Circle the best choice to complete each of the statements about possible places where the matter in the alcohol might go.

How much of the matter in the alcohol goes into the AIR?	***All or most***	Some	None
How much of the matter in the alcohol turns into HEAT AND LIGHT ENERGY?	All or most	Some	***None***
How much of the matter in the alcohol IS BURNED UP AND DISAPPEARS?	All or most	Some	***None***
How much of the matter in the alcohol goes into WATER VAPOR?	All or most	***Some***	None

c. Explain your choices. What happens to the matter in alcohol as it burns?

Level 4 students will explain that all of the matter in the alcohol must still exist as other matter, and may specifically identify carbon dioxide and water vapor as products.

Level 3 students are likely to say that some of the matter is converted into energy.

*Level 2 students are likely to be confused by this question. In particular, they will have trouble distinguishing between **materials**, such as alcohol, which can be destroyed, and **matter,** which cannot be created or destroyed.*

d. Does the alcohol change the air when it burns? ***Yes*** No

e. If you answered "yes" explain how the burning match changes the air.

*Level 4 and some Level 3 students will recognize that the burning alcohol uses oxygen in the air; **Level 4 students will recognize that the oxygen is incorporated into carbon dioxide** (and water vapor, though we do not expect even Level 4 students to mention this).*

Level 2 students are likely to recognize that the alcohol needs air to burn, but they will describe air as an enabler—something that helps the flame—rather than as a kind of material that is altered by the flame.

4. Answer these true-false questions:

True	False	Carbon is a kind of atom.
True	***False***	Carbon is a kind of molecule.
True	False	There is carbon in pure air.
True	***False***	There is carbon in pure water. *(See note below)**
True	False	There is carbon in alcohol.
True	False	There is carbon in wood
True	False	There is carbon in our muscles.

*Only Level 4 students will get this entire sequence of questions correct, (*NOTE: Even some Level 4 students may say "true" to the question about carbon in pure water. Water in the real world is never truly pure, so it will have dissolved carbon dioxide or organic materials.)*

Level 2 and Level 3 students are both likely to struggle with the distinction between atoms and molecules. Level 2 students will probably consider carbon to be a kind of material, which maybe different from other materials. Level 3 students will recognize that carbon might be a component of other materials, but will not be sure which materials include carbon.

Grading the Atoms and Molecules Quiz

Lesson 2, Activity 3

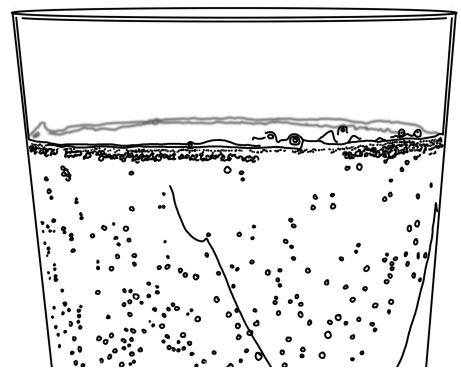
This quiz requires students to apply ideas that they studied in Activities 1 and 2. Conscientious students, even if they started at Learning Progression Level 2, should be able to answer these questions correctly.

*Level 4 (correct) responses to the questions are in **blue bold italics** below. There are also comments connecting the questions to unit activities in blue italics.*

You have studied three important facts about atoms:

1. Atoms last forever (except in nuclear changes).
2. Atoms make up the mass of all materials.
3. Atoms are bonded to other atoms in molecules.

Use these facts and what you have learned about Powers of Ten to answer these questions.



1. These questions are about a glass of soda water that is fizzing.
   a. Do you think that the **oxygen atoms** in the water will still exist as oxygen atoms a million years from now? (Circle your answer)

Yes No Not sure
This is an application of Fact 1, above.

   b. Do you think that the **water molecules** will still exist as water molecules a million years from now? (Circle your answer)

Yes ***No*** ***Not sure***
The best answer to this question would be "not sure." Many water molecules will last for a million years, but some (for example, those used in photosynthesis) will be broken up into H and O atoms. Your students could not know this on the basis of what they have studied so far, though, so either "no" or "not sure" should be counted as correct.

   c. Explain your answers. Use the facts about atoms if they are helpful

The best responses should
--refer to Fact 1 about atoms above (atoms last forever
--point out that Fact 1 applies to oxygen atoms but not water molecules.

2. For each material, decide whether it a kind of atom, a kind of molecule, or both.

Material	***Circle the correct description***		
Water….	…is a kind of atom	***…is a kind of molecule***	…is both a kind of atom and a kind of molecule
Carbon…	***…is a kind of atom***	…is a kind of molecule	…is both a kind of atom and a kind of molecule
Nitrogen….	…is a kind of atom	…is a kind of molecule	***…is both a kind of atom and a kind of molecule***
Carbon dioxide….	…is a kind of atom	***…is a kind of molecule***	…is both a kind of atom and a kind of molecule

3. Explain what the difference is between an oxygen **atom** and an oxygen **molecule.**

The best responses should explain that an oxygen molecule (O_2) consists of 2 oxygen atoms.

4. Someone said that if a boy gains weight, then he MUST have added more atoms to his body. Do you agree?

Yes	No

Explain your reasoning. What is the connection between adding weight and adding atoms?

The best responses should refer to Fact 2 above: Atoms make up the mass of all materials. So no system can gain or lose mass unless atoms move into it or out of it.

Assessing Student Work on Initial Predictions and Explanations Worksheet

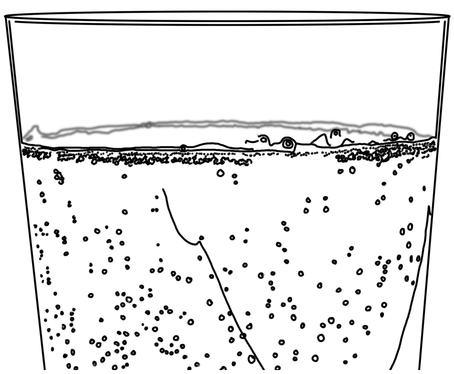
Lesson 3, Activity 2

This worksheet can be especially useful for formative assessment. You can check students' answers to the questions to see how well they connect predicted observations with chemical explanations: their answers to the Movement Question and the Carbon Question.

You will be doing an investigation of soda water fizzing. Here are the tools that you will have:

- A balance that weighs materials accurately to 0.01 grams
- An air-tight (or mostly air-tight) container
- Bromothymol blue (BTB) solution to detect CO_2 in the air inside the container
- Soda water in a shallow glass Petri dish

Make predictions that will help you answer the three questions.

Predictions about mass changes: What are your predictions about objects or materials that will gain or lose mass? What will gain mass? *Check for a **sense of necessity** in students' responses to these questions about mass changes. Do they believe that if the soda water loses mass, then something else (the air in this case) MUST gain mass?* What will lose mass? *Most students will probably predict that the soda water will lose mass, but some Level 2 students may believe that gases have no mass.*	**Predictions about changes in BTB:** Do you think that BTB will change color if it is in a closed container with fizzing soda water? YES NO What color change do you predict? *Many students will probably predict that the BTB will change from blue to yellow. Check below to see what reasoning they are using as the basis for their prediction.*
The Movement Question: Explaining your predictions about mass changes: Draw your ideas about how atoms are moving on the picture below.  Where are atoms moving from? Where are atoms going to? *Check for connections between their predictions about mass changes and their answers to this question: Do they believe that mass changes MUST involve movements of atoms?*	**The Carbon Question: Explaining your predictions about BTB color changes:** What do you think is happening to molecules that have carbon atoms in them? *Check for connections between students' predictions above and their responses to this question.* *Do students have a **sense of necessity** about carbon atoms: If they say that the bubbles contain CO_2, do they have questions about where the carbon atoms in the CO_2 came from?*

Grading Student work on Soda water Fizzing Observations and Conclusions Worksheet

Lesson 3, Activity 3

It would be reasonable to grade these worksheets for completeness and the care students have taken in doing the investigation and recording results. We assume that students will be working in groups of 4, though smaller groups would be appropriate and give more students a chance to work directly with the materials.

A. Steps in the investigation: Check the box as you complete each step.

1. ☐ Add soda water to an open petri dish.
2. ☐ Turn on a digital scale so that it reads “0” g. Place the petri dish with soda water on the scale. Record the masses in the “Measurements during the Investigation” section below.
3. ☐ Place the petri dish into an air-tight container or an inverted clear plastic container.
4. ☐ Fill a petri dish with fresh BTB. On the worksheet, fill in your observation of the color of the BTB.
5. ☐ Place the petri dish with BTB next to the petri dish with soda water into one container and close the container.
6. ☐ After 20 minutes, check the color of the BTB. You may choose to wait longer to observe a final BTB color.
7. ☐ For your last observation of BTB color, open the lid of the container. Record the color of the BTB. Remove the petri dish with the soda water. Weigh the soda water and record the observation on your worksheet.

B. Measurements during the investigation. Record your measurements on the table below.
Results will vary from group to group, but every student should record results from his or her group.

Measurements Before	***Measurements After***
Mass of Petri dish with soda water before Mass: ________________ grams	**Mass of Petri dish with soda water after** Mass: ________________ grams Change in mass: ________________ grams
Color of BTB before Time: ______________________ Color of BTB: __________________________	**Changes in color of BTB** Time: _______________ Color: ___________ Time: _______________ Color: ___________ Change in color: ________________________

C. Results for the whole class: Make notes about how the measurements and observations of other groups in the class compared to yours.

Changes in mass of Petri dish with soda water *Student answers to this question should reflect the class consensus about patterns.*
Changes in color of BTB *Student answers to this question should reflect the class consensus about patterns.*

Grading Student work on Soda Water Molecular Models Worksheet

Lesson 3, Activity 4

*It is reasonable to expect correct responses to this worksheet and to grade students' work accordingly. Correct responses are in **bold blue italics** below, and comments are in regular blue italics.*

A. Using molecular models to show the chemical change. "Carbonated water" gets its name from a weak acid called carbonic acid (H_2CO_3). That's what gives soda its sharp "fizzy" taste. Use the molecular models to figure out how carbonic acid can break up into molecules of water and carbon dioxide when soda water loses its fizz

3. ☐ Make a model of a carbonic acid molecule (H_2CO_3) and put it on the *reactant* side of the Process Tool for Molecular Models poster.
4. ☐ Show how a carbonic acid molecule can come apart, then the atoms can recombine into carbon dioxide (CO_2) and water (H_2O). Make these molecules from your carbonic acid molecule and move them to the *product* side of the Process Tool for Molecular Models poster.

B. Atoms Last Forever!! Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change?

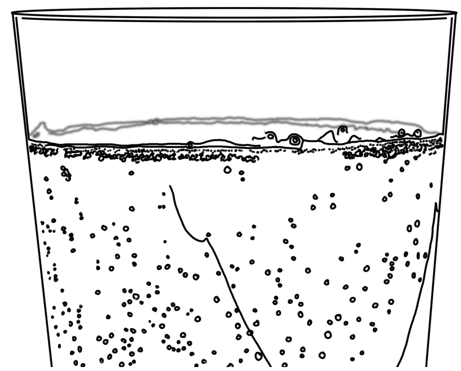
	Matter		
	How many carbon atoms	How many oxygen atoms	How many hydrogen atoms
Began with…			
Carbonic acid	***1***	***3***	***2***
End with…			
Carbon Dioxide	***1***	***2***	***0***
Water	***0***	***1***	***2***
Total number of atoms in products	***1***	***3***	***2***

C. Writing the chemical equation. Use the molecular formulas (H_2CO_3, CO_2, H_2O) and the yield sign (→) to write a balanced chemical equation for the reaction:

$$H_2CO_3 \rightarrow H_2O + CO_2$$

D. Revising your answers to the Movement Question and the Carbon Question. Try revising your answers to the two questions.

1. The Movement Question: Where are atoms moving?
2. The Carbon Question: What is happening to carbon atoms?

1. Bubbles: What molecules are in the bubbles of fizzing soda water? ***Carbon dioxide (or CO_2)*** **2. Changes in mass:** a. What materials *lost mass* due to the movement of atoms? ***Soda water*** b. What materials *gained mass* due to the movement of atoms? ***Air***	**Drawing motions of atoms:** Draw arrows to show how atoms move into, through, and out of the soda water. ***Arrows should to out of soda water and into the air.*** 

Revise your answers to these questions on the Process Tool below.

What happens when soda water loses its fizz?

Soda water

Where are atoms moving from?

H_2CO_3

What molecules are carbon atoms in before the change?
What other molecules are involved?

Chemical change

Air

Where are atoms moving to?

$H_2O + CO_2$

What molecules are carbon atoms in after the change?
What other molecules are involved?

Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)

Assessing Student work on Initial Predictions and Explanations Worksheet

Lesson 4, Activity 1

Students' responses to this worksheet will be useful for formative assessment and for discussion of the results of their investigations. It would NOT be appropriate to grade their responses for correctness. Notes about what to notice about students' responses are below.

You will be doing an investigation of ethanol burning. Here are the tools that you will have:

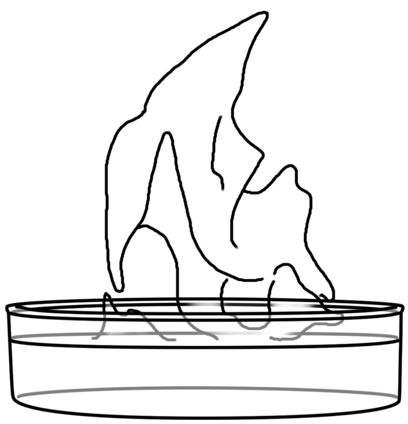
- A balance that weighs materials accurately to 0.01 grams
- An air-tight (or mostly air-tight) container
- Bromothymol blue (BTB) solution to detect CO_2 in the air inside the container
- Ethanol that you can burn in a shallow glass Petri dish

Make predictions that will help you answer the three questions.

<table>
<tr>
<td>Predictions about mass changes: What are your predictions about objects or materials that will gain or lose mass?
What will gain mass?
Do students have a sense of necessity about mass gain and loss? Do they recognize that if the ethanol loses mass, then something else MUST gain mass?
What will lose mass?
Do students have a sense of necessity about the connections between their predictions about mass changes and the Movement Question below--that if the ethanol loses mass, then atoms MUST be leaving it?</td>
<td>Predictions about changes in BTB: Do you think that BTB will change color if it is in a closed container with burning ethanol?

YES NO

What color change do you predict?
Most students will probably predict a color change from blue to yellow. Check to see how their predictions are connected to their ideas about the Carbon Question below. Are they asking where the carbon atoms in the CO_2 came from?</td>
</tr>
<tr>
<td rowspan="2">The Movement Question: Explaining your predictions about mass changes: Draw your ideas about how atoms are moving on the picture below.



Where are atoms moving from?
Do student draw arrows showing BOTH air and ethanol going into the flame?
Where are atoms going to?
Do students connect their arrows with their predictions about mass changes above?</td>
<td>The Carbon Question: Explaining your predictions about BTB color changes: What do you think is happening to molecules that have carbon atoms in them?</td>
</tr>
<tr>
<td>The Energy Question: Explaining changes in forms of energy: How do you think that energy is changing from one form to another?
Some students will use matter-energy conversions as part of their responses. That is OK for now.</td>
</tr>
</table>

Grading Burning Ethanol Observations and Conclusions Worksheet

Lesson 4, Activity 2

It is reasonable to grade students' work on this worksheet.

A. Procedures to follow

1. ☐ Add ethanol to an open glass petri dish.
2. ☐ Turn on a digital scale so that it reads "0" g. Place the petri dish with ethanol on the scale. Record the mass of ethanol in the "Measurements during the Investigation" worksheet.
3. ☐ Fill a petri dish with fresh BTB. On the worksheet, fill in your observation of the color of the BTB.
4. ☐ Place the petri dish with BTB next to the petri dish with ethanol so that the large container lined with aluminum foil fits on top of the two dishes.
5. ☐ Light the ethanol with the lighter and then immediately put the container lined with aluminum foil on top of both the glass petri dish with burning ethanol and the petri dish of BTB. The flame will go out quickly inside the container.
6. ☐ Wait about 20 minutes before taking the lid off the container. Observe and record changes in the color of the BTB during the 20 minutes.
7. ☐ After 20 minutes, remove the ethanol from underneath the container. Place the petri dish on the digital scale and record the mass of the ethanol in the petri dish.
8. ☐ Fill in your observation of the color of the BTB after the experiment.

B. Measurements during the investigation. Record your measurements on the table below.
Each student should be responsible for accurately recording his or her group's measurements and observations.

Measurements Before	***Measurements After***
Mass of Petri dish with ethanol before Time: ______________________ Mass: _________________ grams	**Mass of Petri dish with ethanol after** Time: ______________________ Mass: _________________ grams Change in mass: _________________ grams
Color of BTB before Time: ______________________ Color of BTB: __________________________	**Changes in color of BTB** Time: ________________ Color: ____________ Time: ________________ Color: ____________ Change in color: ________________________

C. Results for the whole class: Make notes about how the measurements and observations of other groups in the class compared to yours.

Changes in mass of Petri dish with ethanol **Changes in color of BTB** *Each student should be responsible for recording class consensus findings about patterns of change in the mass of the ethanol and the color of BTB.*

Grading Explaining What Happens When Ethanol Burns Worksheet

Lesson 4, Activity 3

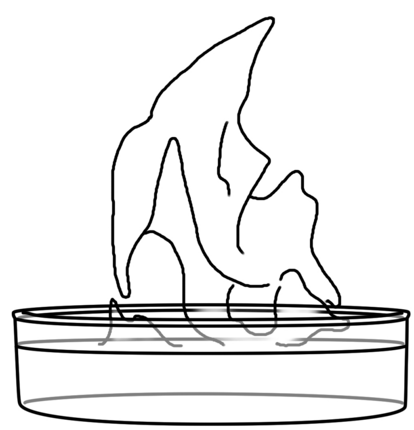
*Students should have correct responses on this worksheet, in **bold blue** below.*

Now let's explain in more detail what happens when ethanol burns. Here's how you will answer the questions:

1. The Movement Question: Where are atoms moving?
   a. You will watch the PowerPoint slides, "Zooming into a Flame."
   b. You will answer the questions below to show the important movements of atoms in a flame.
2. The Carbon Question: What is happening to carbon atoms?
   a. You will use molecular models to make molecules of ethanol and oxygen, then show how the atoms can be rearranged into carbon dioxide and water.
   b. You will write a chemical equation to show how the atoms are rearranged.
   c. You will use the Matter and Energy Process Tool to explain how carbon atoms in ethanol can become carbon atoms in carbon dioxide when ethanol burns.
3. The Energy Question: What is happening to chemical energy?
   a. You will use molecular models identify high-energy bonds (chemical energy) in the molecules involved in ethanol burning.
   b. You will use the Matter and Energy Process Tool to explain how the chemical energy in ethanol is changed into other forms of energy: motion, heat, and light.

A. Answering the movement question

Use the PowerPoint slides "Zooming into a Flame" to answer the questions below.

Bottom of the flame: What kinds of molecules do you see in the bottom of the flame? ***Ethanol or C_2H_5OH*** ***Oxygen or O_2*** ***(Other air molecules could be mentioned)*** Where did those molecules come from? ***Ethanol and air*** What atoms are those molecules made of? ***Carbon (C), hydrogen (H), oxygen (O), (nitrogen (N))***	**Drawing motions of atoms:** Draw arrows to show how atoms move into, through, and out of the flame. ***There should be arrows showing:*** • ***Ethanol entering the flame from the bottom*** • ***Oxygen entering the flame at the bottom*** • ***Carbon dioxide and water leaving the flame at the top.***
Top of the flame: What kinds of molecules do you see at the top of the flame? ***Carbon dioxide or CO_2*** ***Water or H_2O*** ***(Other air molecules could be mentioned)*** Which molecules are different from those at the bottom of the flame? ***Carbon dioxide or CO_2*** ***Water or H_2O*** Are the atoms at the top of the flame different from the atoms at the bottom of the flame? ***No***	

B. Using molecular models to show the chemical change. There are many different kinds of alcohol. The most common is ethanol: This is the kind of alcohol in alcoholic drinks and in biofuels. (The next time you get gasoline, check the pump to see if it says "10% ethanol.")

Ethanol is a good fuel because it has **chemical energy** stored in its high-energy bonds: C-C and C-H bonds. When ethanol burns, it reacts with oxygen (O_2) in the air to produce carbon dioxide (CO_2) and water (H_2O). Since carbon dioxide and water have only low-energy bonds (C-O and H-O), the chemical energy is released as heat and light. Use the molecular models to show how this happens

3. Work with your partner to make models of the reactant molecules: ethanol and oxygen and show how chemical energy is stored in the high-energy bonds of ethanol.
   a. ☐ Make models of an ethanol molecule (C_2H_5OH) and oxygen molecules (O_2, with a double bond). The air has lots of oxygen, so make a few more O_2 molecules than you will need—about 5. Put these molecules on the *reactant* side of the Process Tool for Molecular Models poster.
   b. ☐ Use twisty ties to represent chemical energy. Put a twisty tie around **each** high-energy bond (C-C and C-H bonds) in the ethanol molecule. Note how many energy units (twisty ties) there are in the ethanol molecule.
4. Show how the atoms of the reactant molecules can recombine into product molecules—carbon dioxide and water—and show how chemical energy is released when this happens.
   a. ☐ Take the ethanol and some of the oxygen molecules apart and recombine them into carbon dioxide (CO_2) and water (H_2O) molecules. Put these molecules on the *product* side of the Process Tool for Molecular Models poster. Some things to notice:
      i. How many oxygen molecules reacted with one ethanol molecule? _____
      ii. How many carbon dioxide molecules were produced? _____
      iii. How many water molecules were produced? _____
   b. ☐ Energy lasts forever, so move the twisty ties to the *product* side of the Process Tool for Molecular Models poster. Carbon dioxide and water have only low-energy bonds (C-O and H-O), so what forms does the chemical energy change into?

C. Atoms last forever!! Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change? Use the table below to account for all the atoms and bonds in your models.
Energy lasts forever! Write the type of energy for reactants and products in the chemical change.

	Matter			**Energy**	
	How many carbon atoms	How many oxygen atoms	How many hydrogen atoms	How many twisty ties?	What forms of energy?
Reactants					
Ethanol	***2***	***1***	***6***	***6***	***Chemical***
Oxygen	***0***	***6***	***0***	***0***	
Reactants totals	***2***	***7***	***6***	***6***	
Products					

	Matter			Energy	
Carbon Dioxide	***2***	***4***	***0***		
Water	***0***	***3***	***6***	***6***	***Heat, light, (motion)***
Products totals	***2***	***7***	***6***		

D. Writing the chemical equation. Use the molecular formulas (C_2H_5OH, O_2, CO_2, H_2O) and the yield sign (→) to write a balanced chemical equation for the reaction:

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

E. Revising your answers to the Three Questions. Try revising your answers to the Three Questions using the Process Tool below.

Ethanol, air (into bottom of flame)

Where are atoms moving from?

Ethanol or C_2H_5OH
Oxygen or O_2

What molecules are carbon atoms in before the change?
What other molecules are involved?

Chemical energy (energy in C-C and C-H bonds)

What forms of energy are in the reactants?

Chemical change

Air (at top of flame)

Where are atoms moving to?

Carbon dioxide or CO_2
Water or H_2O

What molecules are carbon atoms in after the change?
What other molecules are produced?

Heat, light, (motion)

What forms of energy are in the products?

Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)

Grading Explaining What Happens When Methane Burns Worksheet

Lesson 5, Activity 1

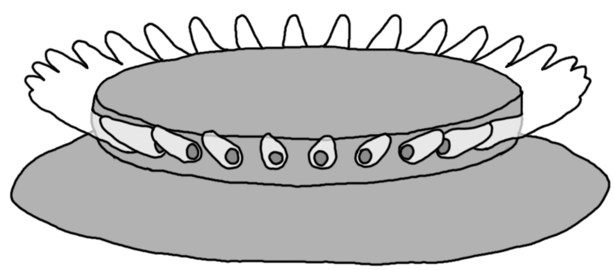
*Students should be able to answer these questions correctly with appropriate coaching. Correct answers are in **bold blue italics** and other comments are in regular blue italics.*

Now let's explain what happens when another fuel burns: Methane or natural gas. Try answering the three questions for what happens when a gas stove burns methane (CH_4). Methane burns in the same way as ethanol burns: molecules of methane combine with oxygen to produce carbon dioxide and water.

To explain what happens when methane burns, you need to answer the three questions:

1. The Movement Question: Where are atoms moving?
2. The Carbon Question: What is happening to carbon atoms?
3. The Energy Question: What is happening to chemical energy?

A. Answering the movement question. Show how atoms are moving in the gas flame.

What kinds of molecules are coming into the bottom of the flame? ***Methane, oxygen, (nitrogen).*** *Nitrogen is present but is not involved in the chemical change.* What kinds of molecules are leaving the top of the flame. ***Carbon dioxide, water, (nitrogen, oxygen).*** *Not all oxygen molecules are involved in the chemical reaction.*	**Drawing motions of atoms:** Draw arrows to show how atoms move into, through, and out of the flame. ***There should be arrows showing:*** • ***Methane entering the flame from the bottom*** • ***Oxygen entering the flamer at the bottom*** *(Stovetop burners actually mix the methane with air before it comes out of the burner, but students will not know this, so arrows showing the oxygen coming from the air are fine.)* • ***Carbon dioxide and water leaving the flame at the top.*** 

B. Using molecular models to show the chemical change. Use molecular models to show what happens when methane burns:

3. Work with your partner to make models of the reactant molecules: methane (CH_4) and oxygen (O_2, with a double bond). Put a twisty tie around **each** high-energy bond (C-C and C-H bonds) in the methane molecule. Put these molecules on the *reactant* side of the Process Tool for Molecular Models poster.
4. Show how the atoms of the reactant molecules can recombine into product molecules—carbon dioxide and water—and show how chemical energy is released when this happens. Take the ethanol and some of the oxygen molecules apart and recombine them into carbon dioxide (CO_2) and water (H_2O) molecules. Put these molecules on the *product* side of the Process Tool for Molecular Models poster. Notice how many of each type of molecule you

have. Carbon dioxide and water have only low-energy bonds (C-O and H-O), so what forms does the chemical energy change into?

C. Atoms last forever! Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change? Use the table below to account for all the atoms and bonds in your models.

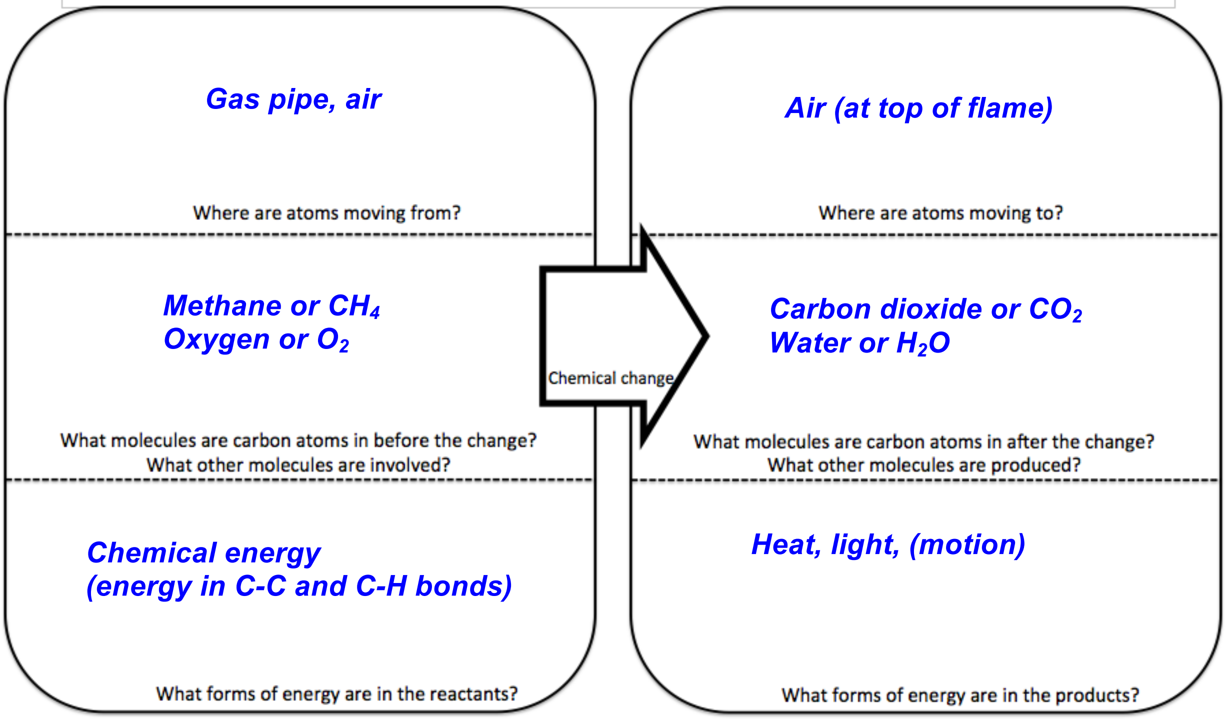
Energy lasts forever! Write the type of energy for reactants and products in the chemical change.

	Matter			**Energy**	
	How many carbon atoms	How many oxygen atoms	How many hydrogen atoms	How many twisty ties?	What forms of energy?
Reactants					
Methane	***1***	***0***	***4***	***4***	***Chemical***
Oxygen	***0***	***4***	***0***	***0***	
Reactants totals	***1***	***4***	***4***	***4***	
Products					
Carbon Dioxide	***1***	***2***	***0***	***4***	***Heat, light***
Water	***0***	***2***	***4***		
Products totals	***1***	***4***	***4***		

D. Writing the chemical equation. Use the molecular formulas (CH_4, O_2, CO_2, H_2O) and the yield sign (→) to write a balanced chemical equation for the reaction:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2\ H_2O$$

E. Using the Process Tool to answer the Three Questions. Answer the Three Questions using the Process Tool below.



Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)

Grading Is it Organic? Worksheet

Lesson 5, Activity 2

*It is reasonable to grade this worksheet. Correct answers are in **bold blue italics.***

Use two different methods to sort the 12 materials on your materials cards into organic and inorganic materials.

A: Sorting based on properties you can see or the origins of materials. Sort the materials based on what you can see or feel or your knowledge of where they came from.

1. Organic materials. In this group you should include:

a. *Foods* or materials made from foods.
b. *Fuels* or materials made from fuels
c. *Bodies of living things* or materials made from the bodies of living things.

List the organic materials below.

Ethyl alcohol, Sugar, Cellulose/Wood, Propane, Butane, Gasoline, Lipids

2. Inorganic materials include materials that are not foods, fuels, or made from the bodies of living things. List the inorganic materials here.

Water, Salt, Limestone, Sand, Air

B. Sorting based on bonds in molecules. Sort the materials based on the kinds of bonds they have in their molecules.

1. Organic materials. In this group you should include materials whose molecules have high-energy bonds: C-C and C-H. List the organic materials below.

Ethyl alcohol, Sugar, Cellulose/Wood, Propane, Butane, Gasoline, Lipids

2. Inorganic materials include materials whose molecules do not have C-C or C-H bonds. List the inorganic materials below.

Water, Salt, Limestone, Sand, Air

C. Chemical energy. What is the difference in chemical energy between organic and inorganic materials?

Organic materials have available chemical energy in C-C and C-H bonds

D. Unknown liquid. How could you tell whether an unknown material—a clear liquid—will burn or not? What tests could you do or questions could you ask to predict whether it will burn?

Students should suggest one of the two criteria in this worksheet:
A. Origins: Is the liquid a food, a fuel, or from the body of a living thing (except water)?
B. Chemical composition: Does the liquid have C-C or C-H bonds?

Grading Other Examples of Combustion Worksheet

Lesson 5, Activity 3

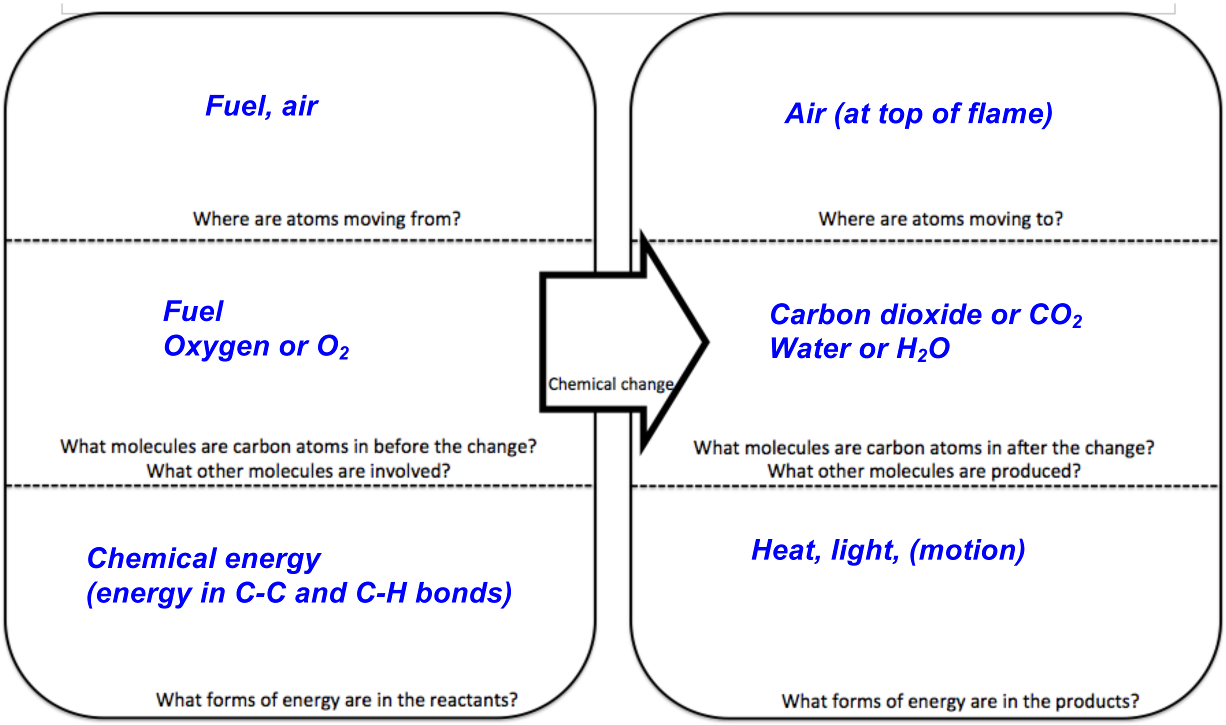
It is reasonable to grade this assignment. General characteristics of correct responses are in ***bold blue italics.***

Choosing examples. Choose two examples of other materials that burn from the list below:

- Methane (CH_4): Natural gas that is used for gas stoves and to heat homes
- Propane (C_3H_8): Used in tanks for gas grills
- Butane (C_4H_{10}): Used in cigarette lighters
- Octane (C_8H_{18}): One of the main components of gasoline
- A burning marshmallow: One of its main components is a sugar, glucose ($C_6H_{12}O_6$)
- A burning candle: Candle wax is a mixture of large hydrocarbon molecules such as pentacosane ($C_{25}H_{52}$).

A. First example: What example of combustion did you choose? ____________________

Using the Process Tool to answer the Three Questions. Answer the Three Questions using the Process Tool below.



Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)

CHECKING YOURSELF: Does you account follow the rules?
Check to be sure that students separate matter and energy in their accounts.

BONUS: Making molecular models. Make a molecular model of the material you chose and show how it can combine with oxygen to produce the products.

BONUS: Writing the chemical equation. Use the molecular formulas and the yield sign (→) to write a balanced chemical equation for the reaction:

Some students may be able to make molecular models and write balanced equations, but we do not suggest this as a requirement for all students.

Grading the Systems and Scale Unit Post-test

Lesson 5, Activity 4

Level 4 (correct) responses to the questions are in ***blue bold italics*** below. There are also comments connecting the questions to unit activities in *blue italics.*

1. Answer these questions about what happens inside the flame of a kerosene lamp (kerosene is $C_{12}H_{26}$)

<table>
<tr><td>Do you think that materials (solids, liquids, or gases) are going into the flame? (circle one answer below)
Yes No I'm not sure</td><td>Do you think that energy is going into the flame? (circle one answer below)
Yes No I'm not sure</td></tr>
<tr><td>What materials do you think are going into the flame?
Air (or oxygen) and kerosene (or kerosene vapor) are going into the flame. This assesses students' understanding of the Movement Question.</td><td>What forms of energy do you think are going into the flame?
Chemical energy in the kerosene is going into the flame. This assesses students' understanding of the Energy question.</td></tr>
<tr><td>Do you think that materials (solids, liquids, or gases) are coming out of the flame? (circle one answer)
Yes No I'm not sure</td><td>Do you think that energy is coming out of the flame? (circle one answer below)
Yes No I'm not sure</td></tr>
<tr><td>What materials do you think are coming out of the flame?
Carbon dioxide and water vapor (and smoke) are coming out of the flame. This also assess students' understanding of the Movement Question and the Carbon Question.</td><td>What forms of energy do you think are coming out of the flame?
Heat (thermal energy) and light energy are coming out of the flame. This also assesses students' understanding of the Energy question.</td></tr>
<tr><td>How do you think that materials are changing inside the flame?
Correct answers would include some representation of a chemical change. For example:
• The atoms of kerosene and oxygen are being rearranged into CO_2 and H_2O.
• A chemical reaction is changing the reactants into the products
• A chemical equation.
This assesses students' understanding of the Carbon Question.</td><td>How do you think that energy is changing inside the flame?
Chemical energy is changed into heat and light. This also assesses students' understanding of the Energy question.</td></tr>
<tr><td colspan="2">What are you not sure about in your answers? Explain what you need to know to answer these questions better.
Look for a sense of necessity in the students' responses. If the students are trying to trace matter and energy but don't understand the details, they are well prepared to learn from this unit.</td></tr>
</table>

1. A scientist started sorting materials into two groups. Here are the first materials that she put into each group:
Group A: *Gasoline, alcohol, wood* ***Group B:*** *Sand, water, steel, carbon dioxide*

a. Which group would you put these materials in?

Salt		Group A	***Group B***
Sugar		***Group A***	Group B
Pork		***Group A***	Group B
Soil minerals that help plants grow		Group A	***Group B***
Leaves of a living tree	***Group A***	Group B	

b. Explain how you decided. How are the materials in Group A different from the materials in Group B?

Students could correctly distinguish the materials in several ways:

- ***Group A materials are organic; Group B materials are inorganic.***
- ***Group A materials have C-C and C-H bonds; Group B materials do not.***
- ***Group A materials have more chemical energy than Group B materials.***
- ***Group A materials have organic carbon; Group B materials do not.***

This assesses students understanding of the nature of organic and inorganic materials.

c. Is there a different way of grouping the materials that makes more sense to you? Yes ***NO****

d. Explain your answer. Why should we have three groups, or why do all the materials fit into two groups?

Level 4 students will recognize that all of the materials can be classified as organic or inorganic and could explain their decisions in several ways:

- ***All of the materials are either organic or inorganic.***
- ***All of the materials are made of molecule that have C-C and C-H bonds or do not.***
- ***All of the materials can be grouped according to how much chemical energy they have.***
- ***All of the materials have a place in the carbon cycle. (*NOTE: Students who say that salt does not have a place in the carbon cycle have reasonable Level 4 answers.)***

This assesses students' understanding of the nature of organic and inorganic materials.

3. When alcohol burns, the alcohol loses weight. What happened to the **matter** that used to be in the alcohol?

a. Which of the following statements is true? Circle the correct answer.

ALL of the matter is still somewhere in the environment, OR
SOME of the matter was consumed by the flame and no longer exists.

b. Circle the best choice to complete each of the statements about possible places where the matter in the alcohol might go.

How much of the matter in the alcohol goes into the AIR?	***All or most***	Some	None
How much of the matter in the alcohol turns into HEAT AND LIGHT ENERGY?	All or most	Some	***None***

How much of the matter in the alcohol IS BURNED UP AND DISAPPEARS?	All or most	Some	***None***
How much of the matter in the alcohol goes into WATER VAPOR?	All or most	***Some***	None

c. Explain your choices. What happens to the matter in alcohol as it burns?

Level 4 students will explain that all of the matter in the alcohol must still exist as other matter, and may specifically identify carbon dioxide and water vapor as products. *This assesses students' commitment to conservation of matter and their understanding of the Movement and Carbon Questions.*

d. Does the alcohol change the air when it burns? ***Yes*** No

e. If you answered "yes" explain how the burning match changes the air.

Level 4 and some Level 3 students will recognize that the burning alcohol uses oxygen in the air; ***Level 4 students will recognize that the oxygen is incorporated into carbon dioxide*** *(and water vapor, though we do not expect even Level 4 students to mention this).* *This assesses students' understanding of the Carbon Question.*

4. Answer these true-false questions:

True	False	Carbon is a kind of atom.
True	***False***	Carbon is a kind of molecule.
True	False	There is carbon in pure air.
True	***False***	There is carbon in pure water. *(See note below)**
True	False	There is carbon in alcohol.
True	False	There is carbon in wood
True	False	There is carbon in our muscles.

This series of questions assesses students' understanding of the nature of organic materials and the connections between systems at the macroscopic and atomic-molecular scales.