Natural Gas and Density

Grade/Subject: 8th Science

Strand/Standard 8.1.5 Develop a model that uses computational thinking to illustrate cause and effect relationships in particle motion, temperature, density, and state of a pure substance when heat energy is added or removed. Emphasize molecular-level models of solids, liquids, and gases to show how adding or removing heat energy can result in phase changes, and focus on calculating the density of a substance's state. (PS3.A)

Lesson Performance Expectations (description): Students will be able to mathematically determine the density of a gas at 2 different temperatures.

Materials:

- Ice water
- Hot water
- Microwave
- fridge or freezer
- scale that can measure the mass difference of a filled balloon and a deflated Balloon (mass to .001)
- 2 balloons per group
- beaker big enough to hold a balloon or a bucket. If you use a bucket, you will need some measuring devices to measure the displaced water.
- Density Tank
- red, blue, and green food coloring
- Infrared temperature gun

Time: 1 class period / 50 minutes

Teacher Background Information:

- OED Natural Gas and Density video:
- Density is a common concept that relates mass to volume. However, some students have some misconceptions. The following PDF details some of these Casual Patterns by Harvard.
- Density is an important property in forming an oil and gas reservoir. Most reservoir rocks are porous and saturated with groundwater before oil or gas enters the rock. Because groundwater is denser, oil and gas can rise upward through the rock. The oil and gas continue to rise until trapped against an impermeable rock, or rock with spaces too small to move through, creating a reservoir. These reservoirs are then discovered by geologists and petroleum engineers and researched to produce the energy source.

- Natural gas is a type of hydrocarbon (fossil fuel) formed over millions of years from the remains of ancient sea plants and animals. It underwent multiple phase changes: solid to liquid to gas. Hydrocarbons were formed from prehistoric plants and animals that lived hundreds of millions of years ago. Over millions of years, the dead plants and animals slowly decomposed into organic materials and formed hydrocarbons. Certain types of hydrocarbons were formed depending on what combination of animal and plant debris was present, how long the material was buried, and what conditions of temperature and pressure existed when they were decomposing.

- Oil and natural gas were created from organisms that lived in the water and were buried under the ocean or river sediments. After the prehistoric seas and rivers vanished, heat, pressure, and bacteria combined to compress and heat the organic material under layers of sediment. In most areas, a thick liquid called oil formed first, but in deeper hotter regions further underground, the heating process continued until natural gas was formed. As the gas forms, it eventually rises above the oil because it is less dense. Natural gas can also be found in tiny pores or fractures in the rock. Sometimes the gas is dissolved in oil and must be extracted.

- Natural gas is a combination of gases (methane, propane, butane, and ethane), but over 80% of its makeup is methane gas. Methane (CH4), the natural gas we use to heat our homes and cook, is the cleanest and most efficient hydrocarbon. Its chemical makeup contains only one carbon atom for every four hydrogen atoms, releasing fewer carbon atoms during combustion. Methane is extremely flammable, and it is also tasteless, odorless, and colorless. A chemical called mercaptan is added to make it smell like rotten eggs to detect leaks more easily.

- Utah's conventional natural gas production is mostly concentrated within Uintah and Grand Counties to the east and Summit County to the north. Utah has 3 of the 100 largest natural gas fields in the country. In 2015, Utah ranked as the 12th largest natural gas producer in the United States (not including production in the Gulf of Mexico). (Source: Utah Geological Survey) This provides economic benefits for the region and the state.

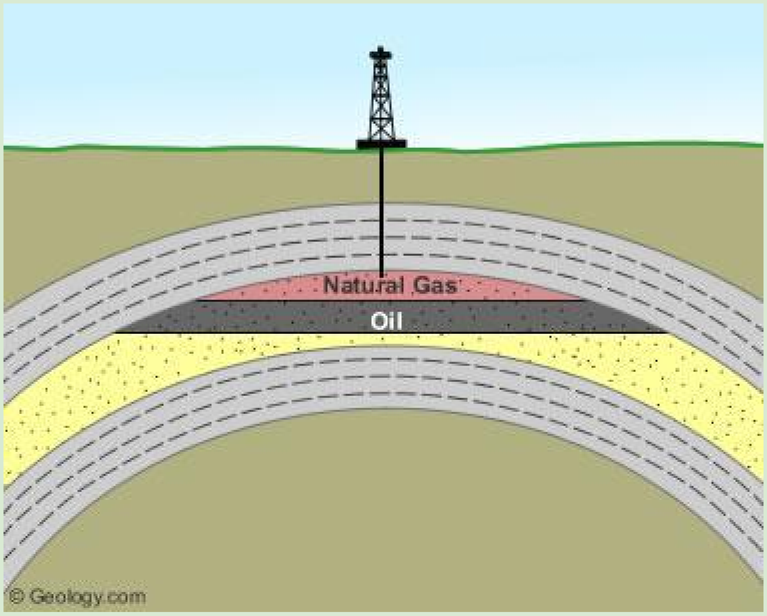
- Natural gas is the cleanest burning hydrocarbon and has become a preferred fuel for electricity generation. Global demand is rising so quickly that producers are struggling to keep up. In the future, more natural gas will come from unconventional sources. Unconventional natural gas is more difficult and less economical to extract than conventional natural gas. However, unconventional wells are productive longer than conventional wells and can help sustain supply over a longer period. The gas is essentially the same substance as conventional natural gas and has the same uses, such as electricity generation, heating, cooking, transportation, and products for industrial and domestic use. New technologies are being developed to accurately estimate the amount of gas in these unconventional reservoirs and stimulate the reservoirs to produce the gas.

Student Background Knowledge: Students should have already had the experience of finding the volume of an object, using water displacement, finding mass, and calculating a density.

Teacher Step by Step: A 3-d lesson should insist students do the thinking. Provide time and space for the students to experience the phenomenon and ask questions. The student sheet provided below provides guidance but is only an example of how students might respond.

1. **Introduce *Phenomenon:*** Have students watch this video, mute the film allowing the students to think. ((1.49 minutes) If the teacher has the skills and equipment, they could demonstrate the video in class. If you are doing the demo in class, you will need an extra-large aquarium, some Dry Ice for each class, and balloons. Be aware of the safety procedures for using Dry Ice. Alternative Phenomenon - use the density tank, hot and cold water, food coloring, and Infrared temperature gun.

2. Ask students what questions they have about the phenomenon. Have them record their questions on their student sheet. Ask several to state their questions out loud. Do not answer their questions.
3. Show students the picture of a natural gas reservoir. Discuss the formation of oil and natural gas. Ask students why Natural Gas is on top of the oil layer.



4. Challenge students to measure the density of a gas and how it changes with the addition of heat energy.
5. Provide Experiences that help students demonstrate other examples. To pique students' ideas, show them an empty balloon and a filled balloon and ask them to tell you how we can measure the properties of the gas inside the balloon (mass, volume, density). Give students time to respond and collect their ideas.

Students should have already completed a lab or seen a demonstration using water immersion to determine the volume of an irregular solid. This same method will be used to determine the volume of a gas. Students find the difference in the masses of the filled and empty balloon to calculate the density. Place the bucket in a large pan or device that catches the water (i.e., oil drip pan), then submerge the balloon into a full bucket; the water will run over the top. Measure water in the pan which gives the volume.

Instructions for Finding Volume

- Inflate the balloon and put it in a fridge for at least an hour. You can do this the day before.
- Fill the bucket with enough cold water to fully immerse the balloon.
- Fully immerse the balloon in the bucket of water. Using a marker, mark the level to which the water rises on the inside of the bucket.
- Remove the balloon. Using the measuring container, add water to the bucket until the water level reaches the mark.
- Record how much water was added in cubic centimeters; this is the volume of the air in the balloon.
- Sketch the balloon showing the particles of air as dots.
- Repeat this procedure after putting the same balloon in a microwave (20 seconds) or hot water before you measure its volume.

Finding the Mass and Density

- Dry the balloon completely.
- Place the balloon on the electronic balance, and record the mass in grams.
- Break the balloon close to the neck. Weigh the broken balloon, and record the mass in grams.
- Subtract the weight of the broken balloon from the weight of the balloon filled with air. This number is the air's mass. Record the mass in grams.
- Divide the mass by the volume. This number is the density of the air. Make sure that the density is expressed in grams per milliliter
- As a class, help them convert grams per milliliter to kilograms per cubic meter.

You might also try this as a “design a lesson: challenge students to come up with a procedure and test out their ideas.

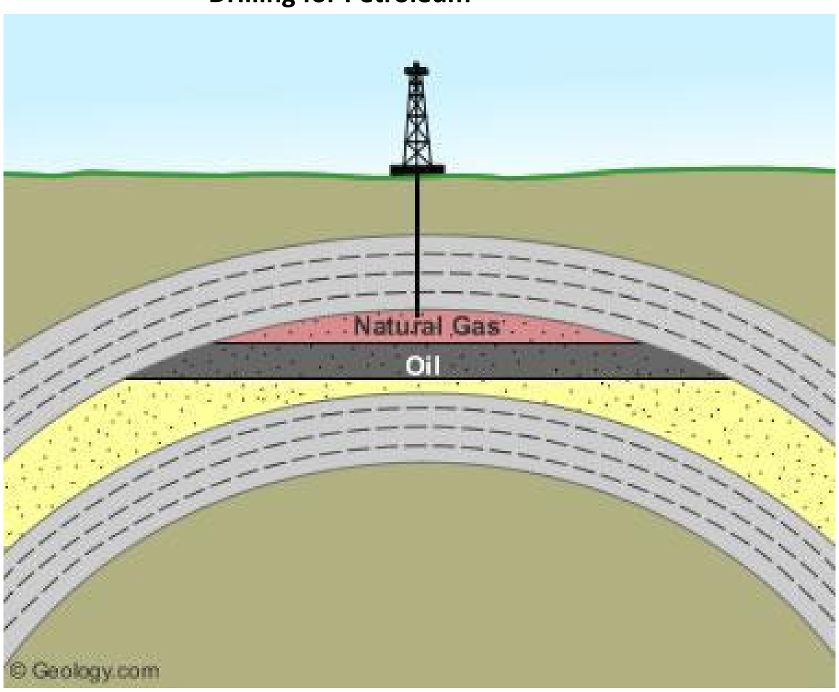
Assessment of Student Learning.

Summarize your experiments using the following words: cause and effect, particle motion, temperature, density, heat energy, and gases:
State your **claim** of what happens to particles when you add heat energy.
List your **evidence** of why this happened.
Explain your **reasoning** for this phenomenon.

Standardized Test Preparation:

Natural Gas: A Lesson on Density of a Gas

Drilling for Petroleum



1. Why are the layers of rock, oil, and gas arranged in this typical pattern?
    a. The rock holds the substances in place.*
    b. The natural gas has hit an impermeable rock layer.*
    c. The oil and natural gas are less dense than the saturated rock below.*

d. The process of drilling the well changes the pressure underground.

Three Petroleum Products

Product	Mass (g)	Volume(cc)
X	14	20
Y	6	10
Z	8.7	1

2. Rank the products by their densities from least dense to densest.
   a. Y, Z, X
   b. X, Z, Y
   c. Y, Z, X
   d. Y, X, Z*

3. A student inflates a balloon and notices it sinks when let go. Why does a balloon filled by a person sink in the air? Choose all that apply.
   a. The plastic of the balloon adds mass.*
   b. The air from the lungs is denser than room air.*
   c. The warm temperature of the air from a body reduces density.
   d. The air in the balloon is under pressure and denser.*

4. A balloon massed empty has a mass of 2 g. After it is blown up and tied off, its mass is 5 g. The balloon is immersed in water. The water level rises by 150 mL. What is the density of the gas in the balloon?
   a. 0.02 g/mL*
   b. 0.03 g/mL
   c. 3 g/mL
   d. 5 g/mL

Extension of lesson:

1. Research and compare Utah's natural gas production with international markets such as Israel and Argentina.
2. Have students interview someone working in the field or at a natural gas plant and share with the class.
3. Have students approximate the density of the air in the room. Give them the average density of air (1.29 kilograms per cubic meter) and have them calculate the rest. Here is a sample script. How Heavy is the Air in the room? Big Ideas: Air has mass. How much do you predict all the air in this room weighs? Let's find out:
   a. Measure the length, width, and height in meters of the room for which you want the mass of air. For example your room has length = 3.7 m (12 ft), width = 3 m (10 ft), and height = 4.3 m (14 ft).
   b. Compute the volume of your room in cubic meters by multiplying length x width x height. In the example, the volume is 3.7 m x 3 m x 4.3 m which equals 47.73 m^3 (cubic meters).
4. What will happen to the air density if the temperature in the room drops 30 degrees?

Career Connections: Potential careers related to this activity are Physicist, Chemist, and Laboratory Technician

Natural Gas: A Lesson on Density of a Gas

Name___________________________________

Phenomenon: Watch the phenomenon. Ask three questions about what they see.
1.

2.

3.

Look at the Natural Gas reservoir picture. Why do you think the gas is on top of the oil layer?

What challenges do you see in measuring the density of a gas?

Pre-lab questions:

1. What does it take to calculate density?
2. What is the formula for density?
3. Write a density problem of your own and answer.

Conduct the two experiments measuring the **air density** in the cold and hot balloons. Show your work.

Cold Balloon:

Warm Balloon:

Using your data, sketch a model of the air particles in both balloons.

Coldwater Balloon	Warmed Balloon

Summarize your experiments using the following words: cause and effect, particle motion, temperature, density, heat energy, and gases:

State your **claim** of what happens to particles when you add heat energy.

List your **evidence** of why this happened.

Explain your **reasoning** for these phenomena.