NATURAL GAS
Formation of a Clean Source of Energy

LESSON SUMMARY

This lesson explores how natural gas was formed by identifying states of matter, density, and how density factors into changes in states. In addition, this lesson connects these science concepts to natural resources and students' daily lives.
(45 minutes)

ACADEMIC STANDARDS

(Will populate with specifics for state)

OBJECTIVES

The student will be able to

- Understand that pressure and temperature affect phase change and how natural gas is formed
- Identify the chemical structure of methane
- Understand why natural gas is the cleanest burning fossil fuel
- Demonstrate how natural gas is formed
- Discover how density affects objects

VOCABULARY

Matter – something that has mass and takes up space
Phase change – the change that matter undergoes shifting from one form to another when temperature changes (heat is gained or lost). States in which matter can exist: a solid, liquid, gas or plasma.
Density – the relationship between the mass of the substance and how much space it takes up (volume)
Physical properties – properties of matter that can be observed or measured without changing the composition of matter. Physical properties include appearance, texture, color, odor, melting point, boiling point, density, solubility, polarity, and many others.
Chemical properties –any of the properties of matter that may only be observed and measured by performing a chemical change or chemical reaction. Chemical properties cannot be determined by touching or viewing a sample
Physical change – a usually reversible change in the physical properties of a substance
Chemical change – a change involving the rearrangement of the atoms of one or more substances and a change in their chemical properties or composition, resulting in the formation of at least one new substance
Natural gas – a flammable gas, consisting largely of methane and other hydrocarbons, occurring naturally underground (often in association with petroleum) and used as fuel
Hydrocarbon – a compound of hydrogen and carbon, such as any of those that are the chief components of petroleum and natural gas.
Methane – a colorless, odorless flammable gas that is the main component of natural gas
Mercaptan – an organic compound that contains sulfur; it is added to methane to create an odor

BACKGROUND INFORMATION

Solids, liquids, gases, and plasmas are different states of **matter** that have different **physical properties**. Each of these states is also known as a **phase**. Elements and compounds can move from one phase to another when specific physical conditions change. For example, when the temperature of a system of matter goes up, its atoms become more excited and active. If enough heat is placed on a substance (or enough pressure is removed), a phase change may occur as the matter moves to a more active state. However, when molecules move from one phase to another they are still the same substance.

Density is one example of a physical property.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{\text{g}}{\text{cm}^3} = \frac{\text{g}}{\text{mL}}$$

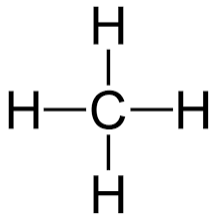
solids **liquids**

Each element and compound has a unique density. But what is density? You may remember experimenting with "sink or float" activities in lower grades. This was testing density. If the items floated, they were less dense than water; if the items sank, they were more dense. But be careful because density is not just about the weight of something. It is the measure of the amount of mass per unit of volume. For example, a Styrofoam cup is less dense than a ceramic mug that is about the same size. A rock is more dense than a crumpled piece of paper the same size. Because gasses have fewer molecules per unit volume, they are less dense than the liquid form of the molecule, and the liquid is less dense than the solid form.

Natural gas is a type of hydrocarbon (fossil fuel) that is formed over millions of years from the remains of ancient sea plants and animals. It underwent multiple phase changes: from solid to liquid and ultimately to gas. Fossil fuels 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 fossil fuels. Different types of fossil fuels 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 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 rock. Sometimes the gas is dissolved in oil, and it has to be extracted.

Natural gas is actually a combination of gases (**methane**, propane, butane, and ethane), but over 80% of its makeup is methane gas. Methane (CH_4), the natural gas we use to heat our homes and cook with, is the cleanest and most efficient natural gas, as its chemical makeup contains only one carbon atom for every four hydrogen atoms, thereby releasing fewer carbon atoms during combustion.



Methane is extremely flammable, but it is also tasteless, odorless, and colorless, so a chemical called **mercaptan** is added to make it smell like rotten eggs so that people can detect leaks easily.

Natural gas is mostly used for home heating, but starting in mid-2004, 2151 MW of new natural-gas-fired electric generating capacity has come online, greatly increasing the amount used by the electric utility sector. (Source: Utah Geological Survey). Natural gas appliances are rising in popularity due to their efficiency and cost effectiveness. Although many natural gas-powered appliances could initially be more expensive than their electric counterparts, they are commonly much cheaper to operate, have a longer expected life, and require relatively low maintenance. Other natural gas appliances include space heaters, clothing dryers, pool and jacuzzi heaters, fireplaces, barbecues, garage heaters and outdoor lights. All of these appliances offer a safe, efficient, and economical alternative to electricity or other fuel sources. The same natural gas pipes that supply gas to a furnace can be used to supply energy for all of the appliances listed above, making installation simple and easy.

Because natural gas is the cleanest burning of the fossil fuels, and it has become a preferred fuel for electricity generation, demand is rising so quickly that producers are struggling to keep up. In the future, more and 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 contribute to sustaining supply over a longer period. The gas is essentially the same substance as conventional natural gas, and it has the same uses, such as electricity generation, heating, cooking, transportation, and products for industrial and domestic use. New technologies are continually being developed to provide more accurate estimations of the amount of gas in these unconventional reservoirs and to stimulate the reservoirs to produce the gas. What are unconventional today may be conventional tomorrow through advances in technology or new innovative processes.

LESSON ACTIVITY

1. Download this free simulation to demonstrate the process of phase change. Allow students to manipulate the demonstration to see what happens. Class Discussion: Discuss what causes changes in states of matter (heat/temperature and pressure). How does pressure factor in to phase changes? If you have access to a vacuum chamber, heat water inside of it, and show how the boiling point of water is lowered when pressure is removed. Explain the density of matter in phase changes and why a gas is less dense than a liquid or a solid.

2. Density is an important property in the formation of an oil and gas reservoir. Most reservoir rocks are porous and saturated with groundwater before oil or gas enters the rock. Because groundwater is more dense, oil and gas is able to rise upward through the rock. The oil and gas continues to rise until trapped against an impermeable rock, or rock with spaces too small to move through, which creates a reservoir. These reservoirs are then discovered by geologists and petroleum engineers and researched for production of the energy source. The following experiment allows the students to test and compare the densities of different objects.

Materials:

100 mL Graduated cylinder
600 mL Beaker
Corn syrup
Water, dyed with food coloring
Vegetable oil
Plastic button
Penny
Glass marble
Wooden bead
Ice cube

Procedure:

1. Pour 100 mL each of corn syrup, vegetable oil, and water into the beaker.
2. Let the liquids settle for a few minutes. Observe what happens.
3. One at a time, gently drop each object into the container.
4. Observe where the objects settle.

3. Students complete **Student Worksheet** questions and then have a class discussion about the questions.
4. Give background and watch a video on natural gas extraction. This Conoco-Phillips video is a great demonstration of how natural gas is extracted.

ASSESSMENT

Students complete **Student Worksheet**
Students will create a model of a methane molecule and describe why methane is the cleanest burning hydrocarbon.

LESSON EXTENSIONS:

1. Research and compare your state's natural gas production with international markets such as Israel and Argentina.
2. Have students interview someone who has a job working in the field or at a natural gas plant about his/her job and share with the class.
3. Invite a guest speaker to video chat with or come to class to talk to the students about what s/he does and what happens in the field.

Student Worksheet

Complete questions 1-3 for the class discussion:

1. How would you compare the densities of the liquids?

2. How would you compare the densities of the solids?

3. Density is defined as mass per unit volume (D = m/v). The density of water is the standard at 1.00 g/cm³. Use the formula for density to calculate the following densities:

1000 cm³ (ml) of oil with a mass of 881 g: _____

100 cm³ (ml) of oil with a mass of 881 g: _____

10 cm³ (ml) of copper with a mass of 89.3 g: _____

200 cm³ (ml) of nickel with a mass of 1780 g: _____

4. If the oil that is heated enough to become natural gas is located deeper underground than the oil, then why is found above oil underground? Discuss what happens to the density of something when it becomes a gas. Does it change or stay the same? Why?

5. Write the chemical structure of methane and propane. Why is natural gas considered a clean burning fossil fuel?

6. Explain density and how it relates to phase changes.

7. Why is the chemical mercaptan added to natural gas?

8. What are some appliances in your home that use natural gas to power them?

9. Work with an adult to research three (3) jobs related to the extraction of natural gas and list them.

Student Worksheet (Answers)

1. How would you compare the densities of the liquids?
Corn syrup is the most dense, then water, then vegetable oil

2. How would you compare the densities of the solids?
Items that sink are more dense than the liquid. Items that float are less dense.

3. Density is defined as mass per unit volume (D = m/v). The density of water is the standard at 1.00 g/cm³. Use the formula for density to calculate the following densities:

1000 cm³ (ml) of oil with a mass of 881 g: _.881 g/ml_

100 cm³ (ml) of oil with a mass of 881 g: _8.81 g/ml___

10 cm³ (ml) of copper with a mass of 89.3 g: __8.93 g/ml_

200 cm³ (ml) of nickel with a mass of 1780 g: _8.9 g/ml__

4. If the oil that is heated enough to become natural gas is located deeper underground than the oil, then how does it end up above the oil in all of the diagrams shown? Discuss what happens to the density of something when it becomes a gas. Does it change or stay the same? Why?
Originally the layer of gas was beneath the layer of oil underground, but because it is less dense than oil, it rises above the oil forming pockets/pools above it. Density decreases when something becomes a gas because the volume increases. (density formula: D=M/V)

5. Why is natural gas considered a clean burning fossil fuel?
It has fewer carbon atoms for every hydrogen atom, so less carbon dioxide is released when it's burned. (See this lesson on Combustion for more.)

Reactants Products

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

Methane oxygen carbon dioxide water

6. Explain density and how it relates to phase changes.
Density is the relationship between mass and volume. The more volume the matter takes up (like in a gas where the molecules are moving freely), the less dense it is than the same amount of matter in smaller volume (like in a solid where the molecules are tightly packed together). Solids are more dense than liquids, which are more dense than gases.

7. Why is the chemical mercaptan added to natural gas?
Because methane has no odor and is so flammable/reactive, mercaptan is added so leaks can be detected.

8. What are some appliances in your home that use natural gas to power them?
Heaters, stoves/ovens (methane), outdoor grills (propane), and more

9. Work with an adult to research three (3) jobs related to the extraction of natural gas and list them.