Title:	A Fluid State of Mind	
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Course:	**Physical Science, Earth Science, Chemistry and Quantitative Literacy, Language Arts**	**Duration:** Three 45-minute class periods
Grade Level:	9-12	

Objective:
The process of hydraulic fracturing is used to extract natural gas and oil from shale rock formations located deep beneath the earth's surface. Students will explore the fluid used in this process while evaluating the composition of the fluid and determining if and how the fluid can be separated into its components.

Summary of Lesson:
Students will learn the basics of the hydraulic fracturing process. Through literary research, they will determine common uses for the components of fracturing fluid. In a laboratory setting, students will then analyze a teacher prepared "sample" of fracturing fluid by determining what separation methods to use, and then separating the sample into its components.

Arkansas Standards:

CODE	GRADE	SLE	STANDARD
Physical Science	**9-12**	**PSI-PS1-1 (PSI-PS1.C)**	Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
Earth Science	**9-12**	**ES-ESS1-6**	Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.
Chemistry	**9-12**	**CI-PS1-8**	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
Quantitative Literacy	**9-12**	**NR.2.QL.1**	Solve real world problems and interpret results involving calculations with percentages, decimals, and fractions • conversions • percent change (absolute vs relative)

			• percent of quantities
		NR.2.QL.2	Use estimation in real world situations • know when • know how • know why
Language Arts	**11-12**	**W.11-12.1.B**	W.11-12.1B Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant evidence and insightful commentary for each while pointing out strengths and limitations of both in a manner that anticipated the audience's knowledge level, concerns, and values, and possible biases.
	9-12	**W.9-10.2** **W.11-12.2**	Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.
	9-12	**W.9-10.4** **W.11-12.4**	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
	9-12	**W.9-10.7** **W.11-12.7**	Conduct short as well as more sustained research projects to answer a question, including a self-generated question, or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Teacher Excellence Support System (TESS):
3a: Communicating with students, 3b: Using discussion techniques, 3c: Engaging students in learning, 3d: Using assessment in instruction

Instructional Strategies and Practices:
Cooperative Learning, Guided Inquiry, Experiments

Bloom's Level: Highest Level Only
Analyzing

Materials and Resources:
Student Handout 1: Fluid State of Mind: A Fluid Situation
Student Handout 2: Fluid State of Mind: Inquiry Lab Form

Student Handout 3: Fluid State of Mind—Lab Separation of a Mixture (for a more guided activity)

Materials per each group of 2-3 students

- 200 mL sample of "fracturing fluid" – see teacher notes
- Ring stand
- Ring clamp
- Funnel
- Filter paper
- (2) 400mL beakers
- (2) 250mL beaker
- Watch glass
- Stirring rod
- Drying oven (optional)
- Bunsen burner
- Balance precise to +/- 0.01

Formative Assessment:
Self and peer assessment, teacher observation and feedback

Summative Assessment:
Lab report

Notes to Teacher: This lesson should follow a short introduction on how natural gas is extracted and processed. Several sources of information are listed below:

(These websites may change over time. If a website is no longer available, use key words and phrases to find more current resources.)

https://www.eia.gov/energyexplained/natural-gas/
https://adventuresinenergy.org/Exploration-and-Production/index.html
http://naturalgas.org/naturalgas/extraction/
http://naturalgas.org/naturalgas/production/

The fracturing fluid used on day one should be prepared beforehand. This is not real fracturing fluid but will simulate the fracturing fluid used. To prepare enough fracturing fluid for 15 student groups, combine 2.7 liters of water (preferably distilled) with 285 grams of sand. Colored playground sand works great, but any pure sand will work as well. Add 15 grams of sodium chloride. The sodium chloride is to account for the other 0.5% chemical additives of which salt is a component. Sodium chloride was chosen for safety. Thoroughly mix the mixture before dispensing to students.

Also see the **Extension activity** at the end of the Student Activity

Student Activity:

Day 1

- Place students into groups of 2-3. Have students watch this video: http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing/hydraulic-fracturing-safe-oil-natural-gas-extraction.

  After viewing the video, see the **Student Handout 1 "A Fluid Situation**." Discuss with students the composition of fracturing fluid.

- Present students with this problem: "We have been asked to analyze a sample of fracturing fluid to determine the mass percent of its components. Your job is to determine what separation methods should be used and then use your procedure to analyze the sample for its mass percent of sand, salt, and water."

- Show students the sample of fracturing fluid. **(See teacher notes for instructions for preparing simulated fracturing fluid.)**

- Have student groups complete **Student Handout 2: Inquiry Lab Form**. Students should write a detailed description of the procedure used to separate the fracture fluid mixture. They should keep in mind what they have researched to be in the fluid. (If a more guided procedure is desired, see the "fluid separation" Student Handout 3.)

Day 2

- Students complete their procedures to analyze the fracturing fluid sample in a laboratory setting. **Using Student Handout 3: Fluid State of Mind—Lab Separation of a Mixture**, students will complete data analysis to determine the mass percent of substances found in the fluid at the beginning of Day 3 or when their samples have dried.

Day 3

- Student groups participate in class discussion to compare their calculations. Theoretical calculations should be approximately 90% water, 9.5% sand, and 0.5% other compounds (salt). Assume this mixture has a density of 1 g/mL.

Extension Activity

1. Students calculate the mass in grams of substances found in fracturing fluid from percent composition.
2. Research how chemicals present in fracturing fluid can be separated from the mixture.
3. Research what happens to fracturing fluid after it is used in obtaining natural gas.

4. Calculate the real density of the teacher made "fracturing fluid" sample.

References

Methods for Separating Mixtures:
https://courses.lumenlearning.com/cheminter/chapter/methods-for-separating-mixtures/

"Hydraulic Fracturing." Video. American Petroleum Institute. http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing/hydraulic-fracturing-safe-oil-natural-gas-extraction

"A Fluid Situation." Energy In Depth. https://energyindepth.org/wp-content/uploads/2011/10/frac-fluid.pdf

Student Handouts: Printable copies of the handouts are available at https://arkansasenergyrocks.com/educators/lesson-plans-9-12/.

Student Handout 1:

A number of excellent graphics showing the chemical make-up of fracking fluids are available. Search the internet using the key phrase "fracking fluid graphics," or use https://energyindepth.org/wp-content/uploads/2011/10/frac-fluid.pdf

Also see: http://geology.com/energy/hydraulic-fracturing-fluids/ for a detailed explanation.

Illustrate one example of fracking fluid below:

Student Handout 2
Fluid State of Mind
Student Handout 2
Inquiry Lab Form

Names:____ Date:_____________________

____ Period:____________________

____

Write down your experiment here (use the back if you need more space)
Record your final lab report on notebook paper or in your lab notebook.

Purpose:

Hypothesis:

Materials:

Procedures: (Remember to be detailed! Someone else should be able to follow your procedure with very few questions. If you need more space, use the back of this page. You will probably need more space.)

Data: (What data are you collecting? Do you need tables, graphs, etc.?)

Conclusion:

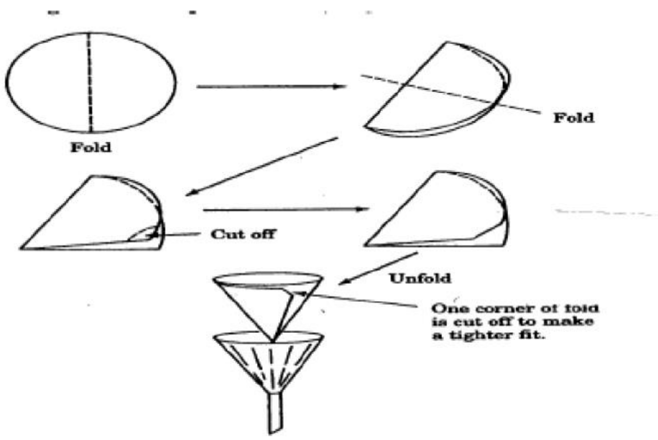
Fluid State of Mind
Student Worksheet 3

LAB - SEPARATION OF A MIXTURE

Chemists often need to separate mixtures of two or more substances. Because a mixture is a ***physical combination*** of materials, the components may be separated using ***physical changes***. There are different ways of accomplishing such a process. One common laboratory technique involves ***distillation***, where substances having different boiling points are separated. Another common technique makes use of differences in the ***solubility*** of the components of the mixture.

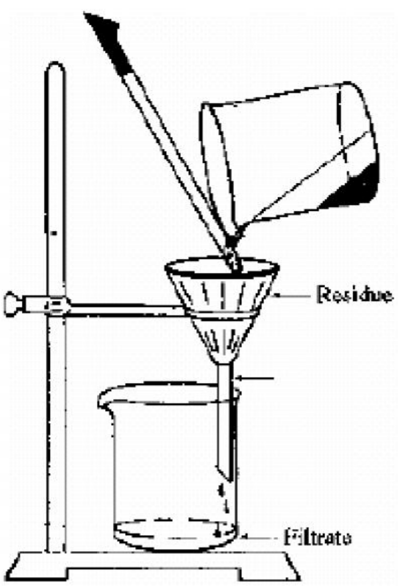
For this experiment you will: receive a mixture of water, sand, and salt; separate the two materials; and eventually determine the ***percentage composition*** of the mixture. You will separate sand from salt by using the difference in their solubility in water. Salt will be separated from water by a simple distillation.

PROCEDURE



1. Prepare a piece of filter paper as shown here.
Obtain the mass of the filter paper and write your name in pencil on an outside edge. Place the filter paper in a funnel as shown. Be sure to separate 3 edges away from 1 edge to create a cone.

2. Attach an iron ring to a ring stand, and then place the funnel into a clay triangle as shown in the next diagram. (A drop or two of water will help the paper stick to the sides of the funnel.)



3. Find the mass of your 400mL beaker. Obtain a sample of the fluid. Find the mass of the beaker with the fluid sample.

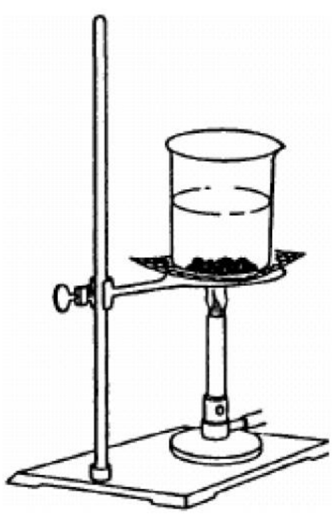
4. Obtain a **different** clean, dry beaker. The 250 ml size is best. Set this beaker under the funnel to collect the ***FILTRATE*** (clear salt-water solution).

5. Pour the sand/saltwater mixture into the funnel. Collect the filtrate, being careful to prevent spattering. Small amounts of additional water may be used to rinse out all of the sand. Be sure to pour all of the water used into the funnel.

6. Rinse the ***RESIDUE*** (wet sand) with a small amount of distilled water from your wash bottle and collect all of the filtrate in the beaker.

7. When all of the water has passed through the filter paper, remove the filter paper from the funnel and blot it with a layer of paper towels to absorb the excess water, and then place the filter paper in the drying oven. You will obtain its mass on the next day.

8. Meanwhile, place the beaker with salt water on a wire mesh on a ring stand. Light the Bunsen burner and evaporate the water by heating it ***gently*** until most of the water is gone. Place the **watch glass** on the beaker when the contents are pasty and start to spatter. Depending on available time, your teacher might have you dry the salt overnight in an oven. In that case, be sure your beaker is clearly labeled with your name(s).



9. When the salt is dry and the beaker is cool, obtain the mass of the beaker, watch glass, and contents.

DATA: Report all visible digits **CALCULATIONS:** show all work neatly, from the balance, including zeroes even if the computation seems "trivial"

Mass of filter paper _____g

Mass of empty beaker _____g

Mass of beaker with sand/salt/water mixture _____g

Mass of sand/salt/water mixture _____g

Mass of filter paper with sand _____g

Mass of empty beaker with watch glass

Mass of beaker with salt and watch glass _____g

*Actual mass of sand obtained ____ g

*Actual mass of salt obtained ____ g

*Mass of water in the original sample ____ g

Analysis:

1. Refer to the original mass of the mixture, and to the actual mass of sand you recovered. What percent of the original mass did the sand contribute? Show the calculation neatly in the space provided.

2. Refer to the original mass of the mixture, and to the actual mass of salt you recovered. What percent of the original mass did the salt contribute? Show the calculation neatly in the space provided.

3. ***Percent yield*** is a common way to evaluate the amount of product you have obtained through laboratory work. Percent yield is determined in the following manner:

% Yield = Actual amount of product obtained dived by Theoretical amount of product possible * 100%.

For the **actual amount of product obtained,** add together your dry salt and dry sand masses.
For the **theoretical amount of product possible**, use the original mass of the mixture before the experiment. (Be sure that you do not include the mass of the container!)
Show the calculation neatly in the space provided.

Discussion - Use complete sentences - be specific with your explanations.

1. Suppose a lab group reports a percent yield of 90%. What is a possible explanation for the "missing"
product? Do not consider calculation mistakes, think about the procedure used.

2. Suppose a lab group reports a percent yield of 105%. Is it really possible to collect *more* sand and salt than was originally present? What is a possible explanation for the "extra" product? Do not consider calculation mistakes, think about the procedure used.

3. Without using any additional equipment/materials, and without touching or blotting the salt, describe a procedure by which you could prove that the salt was completely dry.

4. Complete the following:
   a. Name one *heterogeneous mixture* present in this lab. ___________
   b. Name one *homogeneous mixture* present in this lab. ___________
   c. Name one *pure substance* present in this lab. __________

5. What if your mixture had contained small pieces of **iron** in addition to salt and sand, how could you modify the procedure used in lab in order to separate the mixture? (If you are not sure, look up some properties of iron that are different from sand and salt.)

Conclusion: Summarize in a well-written paragraph (minimum 3 – 5 sentences) how **your results** support the Law of Conservation of Matter. (Your conclusion should begin with a definition of the Law of Conservation of Matter.