Investigation: Fire Ice in the Deep Sea

Overview

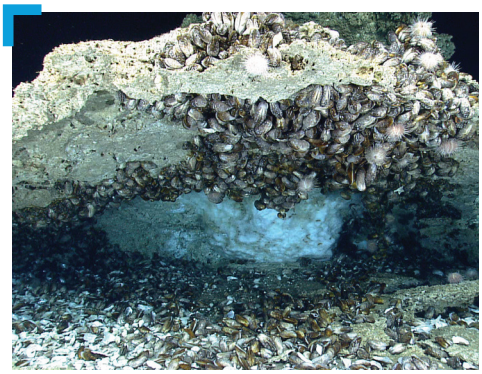
TOPIC: Methane Hydrates on the Ocean Floor

FOCUS: Students will use a variety of resources, conduct an investigation, and participate in group discussions to create a model that explains the conditions under which methane hydrates form.

GRADE LEVEL: 6-8 Physical Science/Earth Science

TIME NEEDED: Two 45- or 50-minute class periods

PHENOMENON/ DRIVING QUESTION: How does methane hydrate form on and below the ocean seafloor?



Large accumulation of hydrates under a ledge as well as a large collection of mussels hanging upside down. *Image courtesy of the NOAA Ocean Exploration.*

OBJECTIVES/ LEARNING OUTCOMES: Students will:

- Develop and use a model to explain the conditions under which methane hydrates form.

MATERIALS:

Methane Hydrate Slides (project for the class)

Student Handouts (one per group, print or share digital copies)

- Student Worksheet: Fire Ice in the Deep Sea (one per student)
- Slide 2: Methane Hydrate Images
- Slide 8: Chemical Structures
- Slide 9: Phase Change Diagrams

Videos (Links have also been embedded into the lesson slides provided.)

- Methane hydrate (frozen methane) and methane gas at Astoria Canyon Floor (1:42) *NOAA Ocean Exploration*
- Cold Seeps and Methane Hydrates (4:51) *MARUM*

Methane Hydrate Formation Activity (set-up for 2-3 students)

- Large and long glass test tube with a #4 stopper with hole
- *Alternative option: Steve Spangler's Large Plastic Test Tubes with Caps*
- 25 ml plain, diluted coffee solution to simulate color of water in squeeze bottle
- Dry ice pellets (3-5 per test tube depending on size)
- Tweezers, tongs and gloves to handle dry ice

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectation (PEs)
MS-PS1-4

Disciplinary Core Ideas (DCIs)
PS1.A: Structure and Properties of Matter

Crosscutting Concepts (CCs)
Cause and Effect
Stability and Change

Science & Engineering Practices (SEPs)
Developing and Using Models
Obtaining, Evaluating, and Communicating Information

COMMON CORE CONNECTIONS
ELA-Literacy RST.6-8.4; 8.7; 8.9

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS
Principle 5: FCs e,g

Overview cont.

EQUIPMENT:
- Video projection or online sharing capability

SET-UP INSTRUCTIONS:

For online learning
- Cue up images and videos for student viewing

For in-person instruction
- Share links or digital copies of all materials listed above with students using a preferred online platform.

Educator Guide

Background

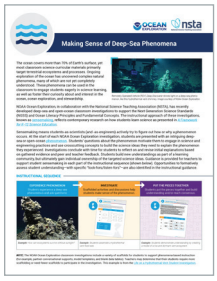
A gas hydrate is an ice-like substance that forms in deep-sea sediments when low-density gas, like methane, ethane, or carbon dioxide, combines but does not chemically bond with water and freezes into a solid under low temperature and moderate pressure conditions. This results in a lattice or rigid cage of water molecules with the gas molecules trapped inside. The resulting solid is stable at temperatures above 0°C when pressure exceeds 1 atmosphere (33 feet of seawater). Gas hydrate beds can leak gasses up through the seafloor into the water, forming a type of cold seep on the ocean floor.

For example, methane ice usually forms when methane and water freeze at high pressures and relatively low temperatures. These conditions are common at specific depths within the seafloor sediment along continental margins. This hydrate may be referred to as "fire ice" because if you hold a methane hydrate nodule in your hand and light it with a match, it will burn like a lantern wick.

Methane hydrates burn and drip water. *Image courtesy J. Pinkston and L. Stern USGS.*

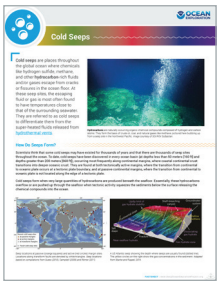
Educator Note

- Students should be familiar with states of matters and thermodynamics.
- A variety of student interaction techniques and examples of student questions are provided throughout this activity to engage students in the process of sense-making to move their learning forward.
- Learn more about the instructional strategies and tools included in the NOAA Ocean Exploration student investigations.



FOR MORE INFORMATION:

- *Cold Seeps Fact Sheet*

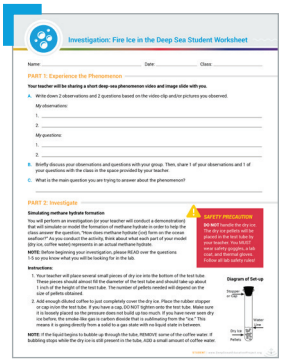


- *Cold Seep Communities Fact Sheet*

Educator Guide

Experience the Phenomenon

- **Distribute** copies of the Student Worksheet: Fire Ice in the Deep Sea (one per student) and Slide 2: Methane Hydrate Images. Tell students they will be observing a video clip and some images about a deep-sea phenomenon. They will be writing down their observations and questions on their worksheet.
- **Play** the Methane hydrate (frozen methane) and methane gas at Astoria Canyon Floor video from **0:25 -0:50** minutes with ***no*** **sound** (the video is also embedded on Slide 1). After the video, you may project Slide 2: Methane Hydrate Images for the class to view if colored copies are not available.
- In groups of 2-3 students, give students time to look over the images and fill in **Part I** of their Student Worksheet to discuss their ideas. Provide a white board or other space where students can share their work as a class after they have finished their group conversations. Then, briefly discuss their observations/questions as a class.


Investigation: Fire Ice in the Deep Sea Student Worksheet

Name: _____ Date: _____ Class: _____

PART 1: Experience the Phenomenon

Your teacher will be sharing a short deep-sea phenomenon video and image slide with you.

A. Write down 2 observations and 2 questions based on the video clip and/or pictures you observed.

My observations:

1. _____

2. _____

My questions:

1. _____

2. _____

B. Briefly discuss your observations and questions with your group. Then, share 1 of your observations and 1 of your questions with the class in the space provided by your teacher.

C. What is the main question you are trying to answer about the phenomenon?

_____

PART 2: Investigate

Simulating methane hydrate formation

You will perform an investigation (or your teacher will conduct a demonstration) that will simulate or model the formation of methane hydrate in order to help the class answer the question, "How does methane hydrate (ice) form on the ocean seafloor?" As you conduct the activity, think about what each part of your model (dry ice, coffee water) represents in an actual methane hydrate.

NOTE: Before beginning your investigation, please READ over the questions 1-5 so you know what you will be looking for in the lab.

SAFETY PRECAUTION

DO NOT handle the dry ice with your hands. Use tongs or gloves to place it in the test tube by your teacher. You MUST wear safety goggles, a lab coat, and thermal gloves. Follow all lab safety rules!

Instructions:

1. Your teacher will place several small pieces of dry ice into the bottom of the test tube. These pieces should almost fill the diameter of the test tube and should take up about 1 inch of the height of the test tube. The number of pellets needed will depend on the size of pellets obtained.

2. Add enough diluted coffee to just completely cover the dry ice. Place the rubber stopper or cap in/on the test tube. If you have a cap, DO NOT tighten onto the test tube. Make sure it is loosely placed so the pressure does not build up too much. If you have never seen dry ice before, the smoke like gas is carbon dioxide that is sublimating from the "ice." This means it is going directly from a solid to a gas state with no liquid state in between.

NOTE: If the liquid begins to bubble up through the tube, REMOVE some of the coffee water. If bubbling stops while the dry ice is still present in the tube, ADD a small amount of coffee water.

Diagram of Set-up

Dry Ice Coffee Water

As a class, briefly talk through what the students have shared. Hopefully, one of the questions they had was about the formation of what they were seeing. If not, focus on the driving question "How does methane hydrate form on and below the ocean seafloor?" when you give them a brief background using Background Slides 3-4.

Students may ask questions like:

- Where are the bubbles coming from?
- How can there be ice on the seafloor?
- How does this ice form?
- How deep in the sea was the video/image taken?

Investigate

Simulating Gas Hydrate Formation

- **Tell** students they will perform an investigation that will simulate formation of methane hydrate on the seafloor so they can begin to understand and how to answer the driving question.

  Review the instructions for Part 2 as a class or have students read them on their student worksheet. Slide 5: Diagram of Lab Set-up can be projected for the class if needed.

  1. Using tweezers, have students place several small pieces of dry ice into the bottom of the test tube. These pieces should almost fill the diameter of the test tube and should take up about 1 inch of the height of the test tube. The number of pellets needed will depend on the size of pellets obtained.
  2. Have students add enough diluted coffee to just completely cover the dry ice and then place the rubber stopper or cap in/on the test tube. If students are using the large plastic test tubes with caps, make sure they **DO NOT** tighten the cap onto the test tube, but instead, place it loosely so the pressure does not build up too much. As an additional safety precaution with the plastic test tubes, a hole can be drilled through the cap of the plastic test tube.

TEACHER NOTE

Students will need to REMOVE some of the coffee water if the liquid begins to bubble up through the tube. Or, they will need to ADD a small amount of additional coffee water, if bubbling stops while the dry ice is still present in the tube.

TEACHER NOTE

SAFETY PRECAUTION

Students should NOT handle the dry ice. Use tongs/tweezers to transfer the dry ice into the test tubes. Makes sure you are in a well ventilated space. Safety goggles, a lab coat, and thermal gloves should be used by all participants. Please consult your school district or lab safety officer for further clarification and rules pertaining to your state on the use of dry ice in the classroom.

Educator Guide cont.

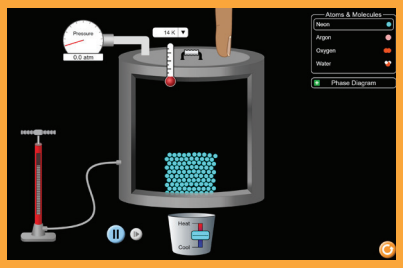
Have students fill in the observation questions in **Part II** of their Student Worksheet. Then, briefly discuss their observations as a class using their test tube hydrates or use Methane Hydrate Lab Slides 6-7.

Distribute copies of Slide 8: Chemical Structures and Slide 9: Phase Change Diagram or project them for the class and redirect students to the driving question. Go over the slides as a class or have students work through them as a group. They should be able to answer the questions under the "Dry Ice Model versus Methane Hydrate" heading on page 2 of their worksheet.

Students may ask questions like:

- How can methane hydrates form in places that aren't freezing?
- Can you have a gas and a solid at the same place? How?
- How deep are methane hydrates? How do we even know they exist?

A great alternative to the phase diagram slide is to use the PHET Simulation for Phase Changes. This provides a visual tool for students to use and see how pressure and temperature affect the states of matter at the molecular level.



Put the Pieces Together

Redirect the students to the driving question. Show them Cold Seeps and Methane Hydrates video (0:30 – 3:17 min) to help them bring their ideas together (Slide: 11). Then, ask them to work together and draw a model that best explains **how methane hydrates form on the seafloor** and **how the methane gas is released**.

Guide students to draw on all the evidence they have recorded from the videos and images, questions they have answered, and the class discussions. Remind them to identify the components and the relationships between those components in order to make their thinking as visible as possible.

Give students time to draw their model. As students work, circulate around the room to get a sense of what ideas students are using to construct their explanations.

Extensions

- **Natural Gas Formation:** This investigation provides students the opportunity to observe the production of methane from decaying organic materials. Your school may have hand-held methane detectors you could use to conclusively identify the gas produced in this investigation as methane.
- **Methane Hydrate Model (pages 14-19):** If this lesson is taught as part of a unit on chemical reactions and physical changes (phase changes and mixtures), you might choose to have students create three-dimensional models of water (liquid and solid phases), methane, and methane hydrate to support students' understanding of methane hydrate as a mixture of water and methane, not a new substance.

Scientific Terms

Methane: CH_4 is a hydrocarbon that is a primary component of natural gas.
Methane hydrate: Water ice crystal structures that contain methane gas locked (not chemically bonded) in a cage-like structure.
Cold seeps: Places throughout the ocean where hydrogen sulfide, methane, and other hydrocarbon-rich fluids and/or gasses escape from cracks in the ocean floor.
Water pressure: The amount of force per unit area that water puts on a surface. The more water there is above, the more it pushes against the state of matter, seafloor, object, or organism.
Phase change: When matter changes from one state (solid, liquid, gas, plasma) to another.
Sublimation: The transition of a substance directly from the solid to the gas state, without passing through the liquid state.

Assessment

Opportunities for formative assessment are embedded throughout the lesson through class discussions. The student explanations and drawings that are developed at the end of the lesson could be used as an opportunity for summative assessment.

Investigation: Fire Ice in the Deep Sea

Page 1:
- Methane hydrate (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/logs/apr12/apr12.html
- Methane Hydrate Slides: https://oceanexplorer.noaa.gov/edu/materials/methane-hydrate-slides.pdf
- Student Worksheet: Fire Ice in the Deep Sea: https://oceanexplorer.noaa.gov/edu/materials/fire-ice-in-deep-sea-student-worksheet.pdf
- Methane hydrate (frozen methane) and methane gas at Astoria Canyon Floor (video): https://www.youtube.com/watch?v=OazBJkRlAmA&t=1s
- Cold Seeps and Methane Hydrates (video): https://www.youtube.com/watch?v=ahmjHLyF9GM

Page 2:
- Ocean Exploration Facts: https://oceanexplorer.noaa.gov/facts/hydrates.html
- Methane Hydrate (image): https://www.usgs.gov/media/images/gas-hydrates-burning
- Making Sense of Deep-Sea Phenomena (PDF): https://oceanexplorer.noaa.gov/edu/materials/NOAA-NSTA-sensemaking-phenomenon.pdf
- Cold Seeps Fact Sheet (PDF): https://oceanexplorer.noaa.gov/edu/materials/cold-seeps-fact-sheet.pdf
- Cold Seeps Communities Fact Sheet (PDF): https://oceanexplorer.noaa.gov/edu/materials/cold-seep-communities-fact-sheet.pdf

Page 3:
- Student Worksheet: Fire Ice in the Deep-Sea (PDF): https://oceanexplorer.noaa.gov/edu/materials/fire-ice-in-deep-sea-student-worksheet.pdf
- Methane Hydrate slides: https://oceanexplorer.noaa.gov/edu/materials/fire-ice-in-deep-sea-slides.pdf
- Methane hydrate (frozen methane) and methane gas at Astoria Canyon Floor (video): https://www.youtube.com/watch?v=OazBJkRlAmA&t=1s

Page 4:
- PHET Simulation for Phase Changes: https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html
- Student Worksheet: Fire Ice in the Deep Sea (PDF): https://oceanexplorer.noaa.gov/edu/materials/fire-ice-in-deep-sea-student-worksheet.pdf
- Cold Seeps and Methane Hydrates (video): https://www.youtube.com/watch?v=ahmjHLyF9GM
- Methane Hydrate slides: https://oceanexplorer.noaa.gov/edu/materials/fire-ice-in-deep-sea-slides.pdf
- Natural Gas Formation (investigation): https://www.earthsciweek.org/classroom-activities/natural-gas-formation
- Cold Seeps and Methane Hydrates (video): https://www.youtube.com/watch?v=ahmjHLyF9GM
- Methane Hydrate Model (pdf): https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_bigdeal.pdf

Partners

OCEAN EXPLORATION

SCHMIDT OCEAN INSTITUTE

NAUTILUSLIVE.ORG
OCEAN EXPLORATION TRUST

Created in cooperation with the National Marine Sanctuary Foundation under federal award NA19OAR0110405 for the Deep Ocean Education Project.

Information and Feedback

We value your feedback on this activity, including how you use it in your formal/informal education settings. Please send your comments to: **oceanexeducation@noaa.gov**. If reproducing this activity, please cite NOAA as the source, and provide the following URL: https://oceanexplorer.noaa.gov.