MATH AND SCIENCE @ WORK

AP* CHEMISTRY Educator Edition

DIVING DOWN DEEP

TI-Nspire™ Lab Activity

The Math and Science @ Work Biology problem, Preventing Decompression Sickness on Spacewalks, addresses a similar topic, and may be used to reinforce and assess the material learned from this lab.

Instructional Objectives

Students will

- explore and apply gas laws;
- add pressure to a bottle and determine the moles of gas added using the ideal gas law;
- create and interpret a mathematical model as it relates to the experiment performed; and
- relate findings from the experiment to a real-world situation.

Teacher Preparation

- Distribute the TI-Nspire file, *Diving_Down_Deep.tns*, to the students' handhelds.
- Have the following materials and equipment available for each lab station:
  - TI-Nspire Lab Cradle or Vernier EasyLink cable
  - Pressure probe
  - Temperature probe
  - Plastic bottle (with a volume of at least 0.5 L)
  - Syringe and a three-way valve (two-way valve will work with a little more effort from students)
  - Pressure/fill cap: a two-hole stopper with two ports—one for the pressure probe and one for the syringe (Figure 1)
  - Safety glasses and aprons

Grade Level
10–12

Key Topic
Gas Laws

Teacher Prep Time
30 minutes

Lab Time
70–90 minutes

Materials/Equipment
- TI-Nspire handhelds
- TI-Nspire file: *Diving_Down_Deep.tns*
- TI-Nspire Lab Cradle or Vernier EasyLink™ cables
- Pressure probes
- Temperature probes
- Plastic bottles
- Syringes
- Three or two-way valves
- Pressure/fill caps
- Safety glasses and aprons

AP Course Topics
Gases:
- Laws of ideal gases

NSES Science Standards
- Physical Science
- Unifying Concepts and Processes

Figure 1: Bottle with pressure/fill cap

Safety Considerations

Students should be aware of safety considerations (also found on the student handout).

- Wear safety glasses and aprons.
- Under high pressure, the plastic bottle can fracture or the stopper can pop out of the bottle. Point stopper away from others.

Class Time Required

This lab requires 70–90 minutes.

- Introduction: 5–10 minutes
- Student Work Time: 60–70 minutes
- Post Discussion: 5–10 minutes

AP Course Topics

Gases

- Laws of ideal gases
  - Equation of state for an ideal gas
  - Partial pressures

NSES Science Standards

Physical Science

- Structure and properties of matter

Unifying Concepts and Processes

- Evidence, models and explanation
- Change constancy, and measurement

Background

This lab activity is part of a series of activities that applies Math and Science @ Work in NASA's research facilities.

The Neutral Buoyancy Laboratory (NBL) is a deep pool located inside the NASA Sonny Carter Training Facility in Houston, Texas. The NBL is 61.6 m (202 ft) long, 31.1 m (102 ft) wide, and 12.2 m (40 ft) deep, which allows two different training activities to be performed simultaneously at either end of the pool. The NBL is large enough to hold full-sized models of International Space Station (ISS) modules, spacecraft (like the Orion Crew Multi-Purpose Crew Vehicle) and flight payloads.

The NBL uses neutral buoyancy to train astronauts for spacewalks. Being in a neutrally buoyant state is similar to the feel of weightlessness in space. In a neutrally buoyant state, an object has an equal tendency to float as it does to sink. Objects in the NBL, including humans, are made neutrally buoyant using a combination of weights and flotation devices. In such a state, even a heavy object can be easily manipulated, as is the case in the microgravity of space.

When training in the NBL, astronauts wear pressurized Extra-vehicular Mobility Unit (EMU) suits, the same as those worn in space. Out of the water, these EMU suits weigh approximately 127 kg (280 lbs). During training, the EMU-suited astronauts are assisted by at least four professional support divers wearing regulation SCUBA gear.

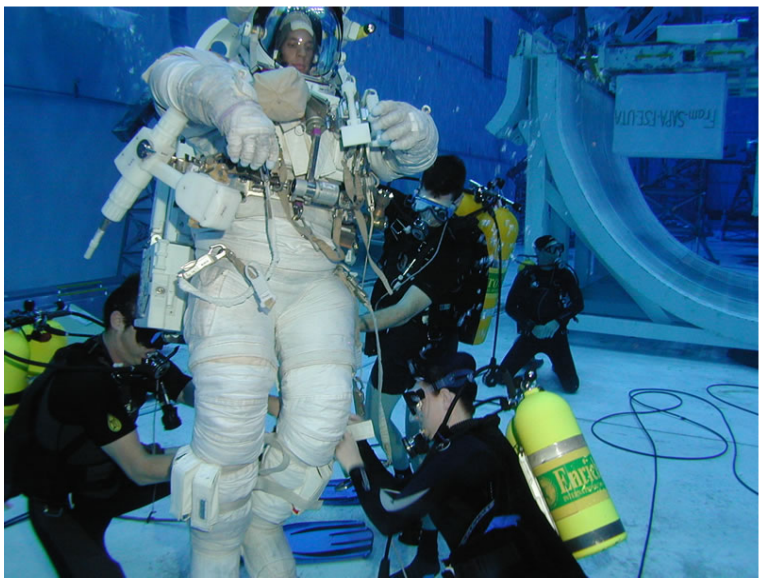


Figure 2: An astronaut and assisting SCUBA divers in the Neutral Buoyancy Laboratory

For every hour the astronaut is scheduled for a mission spacewalk, the dive team will spend seven hours training in the water. On a training day at the NBL, astronauts normally spend up to six consecutive hours in the pool. The support divers, however, are limited to five hours of dive time per day, broken into at least two different dives of two to three hours per session.

The support divers and the astronauts use a special mix of gas known as nitrox, allowing them to stay under water for their dive sessions without decompression. The nitrox mixture used by the NBL consists of 45% oxygen and approximately 55% nitrogen, and is compressed into two different sizes of dive tanks. The support divers wear a system containing either two small or two large dive tanks.

The smaller-sized tanks are each 6.95 liters in volume, and at standard temperature and pressure each tank contains 1,416 liters of compressed nitrox. The larger-sized tanks are each 11.1 liters in volume, and at standard temperature and pressure each tank contains 2,265 liters of compressed nitrox. The size of the diver and the depth of the dive both determine the rate of nitrox consumption for the dive. Divers use these factors to choose which size of tanks they will use for each dive.

Lab Procedure

With your lab partner, gather the required materials and equipment. On your TI-Nspire handheld, open the file, *Diving_Down_Deep*. Read the provided information and answer the pre-lab questions

(TI-Nspire pages 1.1–1.5). You will then be ready to start the lab activity. Go to TI-Nspire page 2.1 and follow the provided instructions. After completion of the lab activity, proceed to the lab analysis on TI-Nspire pages 2.16–2.27.

Solution Key

Throughout this activity, students are given most of the information and questions in the TI-Nspire file, *Diving_Down_Deep.tns*. Students are also provided with the questions on the student handout. Some screenshots have been provided throughout the solution key to show what students will be reading on their handhelds. A TI-Nspire file with the solutions, *Diving_Down_Deep_Solutions.tns*, is also provided enabling discussion of the solutions (using TI-Nspire software and a projector).

Mission (TI-Nspire pages 1.1–1.3)

The NBL support divers assist the astronauts as they train for spacewalks in the NBL. The astronauts are in the water for up to six-hour sessions, and divers are in the water for up to two to three-hour sessions. The support divers use either a system of twin 6.95-liter tanks (containing a total of 2,832 liters of compressed nitrox) or a system of twin 11.1-liter tanks (containing a total of 4,530 liters of compressed nitrox).

In this activity, you will explore a method for adding air to a gas cylinder diving tank, and determine the amount of gas needed by a support diver during a diving session.

Pre-Lab Questions (TI-Nspire pages 1.4–1.6)

1.4 Assume that a fixed volume container is kept at constant temperature. How can the pressure be increased?

The pressure can be increased by adding more moles of gas.

1.5 What causes the pressure in (what appears to be) an empty bottle?

There are gas molecules contained in the bottle.

1.6 If more moles of gas are placed into the bottle at a constant temperature, what will happen to the pressure?

The pressure will increase with the number of moles of gas.

Lab Activity (TI-Nspire pages 2.1–2.6)

Students are given lab instructions in the TI-Nspire file. Screenshots are provided below, ordered from left to right. Note that even though one handheld is collecting the data, all students' handhelds may be used to complete the activities using the data found from the collection. Students' results will vary depending on the elevation that the data is collected.

2.1 2.2 2.3 *Diving_Dow...-12

Lab Instructions

1. Determine the volume of the bottle and record in the spreadsheet on page 2.2.

2.2 2.3 2.4 *Diving_Dow...-12

	A	B measure	C units	D
1		_	_	
2	Bottle Volume	635.	ml	
3	Temperature	19.3	c	
4	Initial Pressure	683.5	mmHg	
5				

A8

2.1 2.2 2.3 *Diving_Dow...-12

2. Connect the temperature and pressure probe to the lab cradle and the stopper. If you have an EasyLink, only use the pressure probe during the experiment and check the temperature at the end. *Note: The temperature probe will record the temperature of the room which is the same as the temperature inside the bottle.*

2.4 2.5 2.6 *Diving_Dow...-12

3. Connect the syringe to the top of the bottle.

4. Plug the Lab Cradle or EasyLink into the handheld.

5. On page 2.7, set up sampling. Press **menu > Experiment > Collection Mode > Events with Entry**. Name the events "pumps" and then press **OK**. If needed change units to mmHg for pressure and °C for temperature. Do this by pressing **menu >**

2.5 2.6 2.7 *Diving_Dow...-12

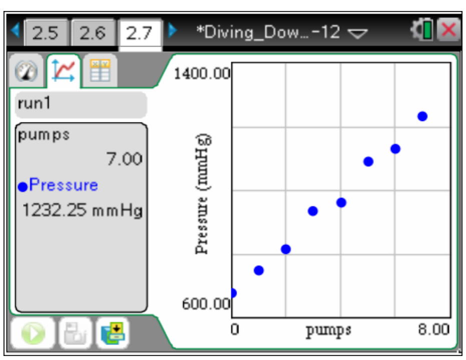
6. **Start sampling** by pressing the collect button in bottom left. **Capture** the initial reading by clicking on the camera. Enter the value of 0.

7. Close the valve to the bottle and fill the syringe from the atmosphere. Then open the valve to the bottle and release the volume of the syringe into the bottle. **Capture** the pressure reading and enter the value 1.

2.4 2.5 2.6 *Diving_Dow...-12

8. Repeat step 7 adding another full pump of the syringe to the bottle and **capture** the pressure reading entering the value 2.

9. Continue this process until you have readings captured from 0 to 7 pumps. Then **stop sampling** by clicking the stop button.



Lab Questions (TI-Nspire pages 2.8–2.15)

2.8 What happened to the pressure in the bottle with each pump?

The pressure in the bottle increased.

2.9 What type of relationship is there between the number of pumps and the amount of pressure?

A linear relationship

2.10 With each pump, what is happening to the gas inside the bottle? Choose all that apply.

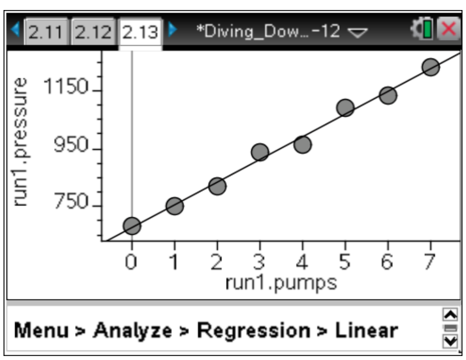
A. *Pressure increases*
B. *Temperature increases*
C. *Moles increase*

2.11 The number of moles of gas is inversely related to the pressure. True or false? Explain your answer.

False. As moles of gas increase, the pressure in the bottle also increases. The moles of gas are directly related to the pressure, not inversely.

2.12 Determine the linear regression for the data.

On page 2.13, graph pumps on the *x*-axis (independent variable) and pressure on the *y*-axis (dependent variable), then press **Menu > Analyze > Regression > Linear** to determine the regression.



2.14 What does the slope of the linear regression model represent in context with this experiment?

The slope of the model represents the predicted increase in the amount of pressure produced by each pump of the syringe.

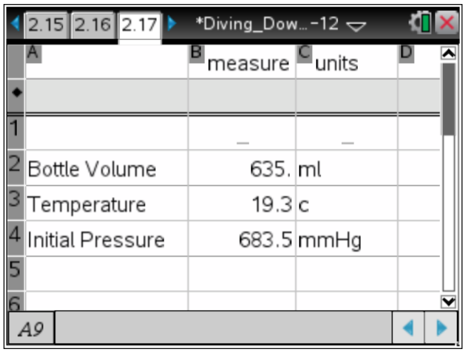
2.15 What does the *y*-intercept of the linear regression model represent in this experiment?

a) *Initial pressure*
b) *Initial volume*
c) *Initial rate*
d) *None of the above*

Lab Analysis (TI-Nspire pages 2.16–2.27)

Temperature of the room, local atmospheric pressure, and the syringe sizes used will affect the data collected. In addition, students' data will vary and this will cause a variance in the answers to the questions asked. Screenshots below show sample data for the experiment.

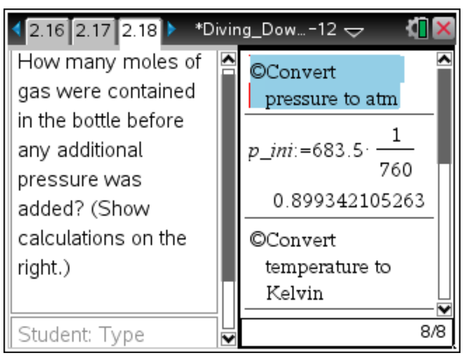
Use the information collected at the beginning of the lab (page 2.17) and the data collected during the lab to answer the following questions.

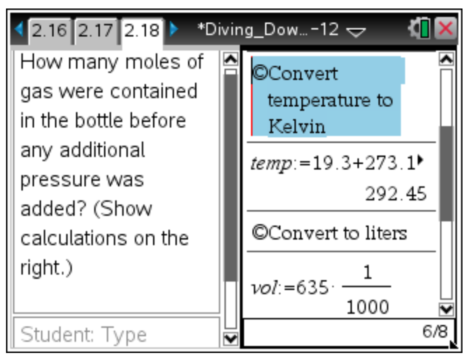


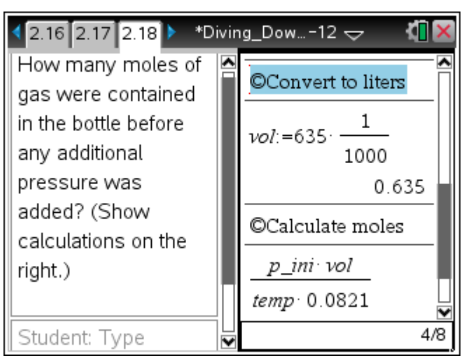
	A	B measure	C units	D
1				
2	Bottle Volume	635.	ml	
3	Temperature	19.3	c	
4	Initial Pressure	683.5	mmHg	
5				

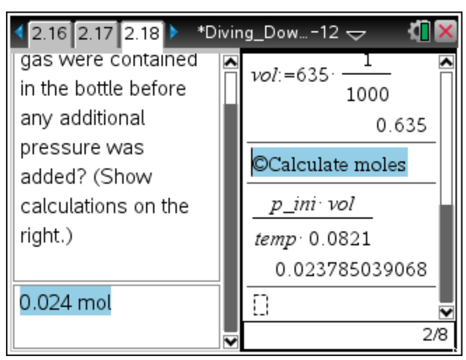
2.18 How many moles of gas were contained in the bottle before any additional pressure was added?

Moles will vary depending on the temperature and the local atmospheric pressure.



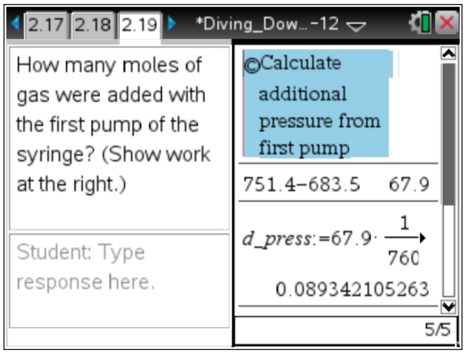


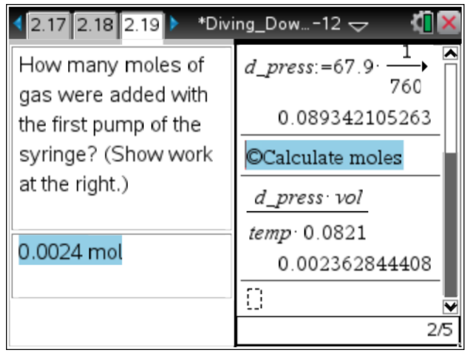




2.19 How many moles of gas were added with the first pump of the syringe?

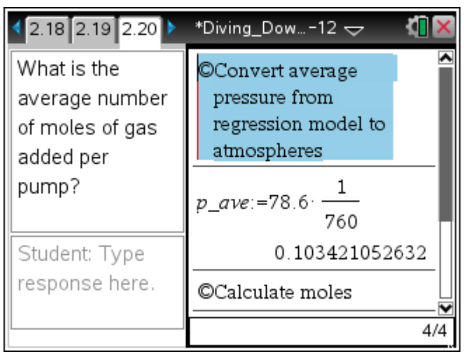
Moles will vary depending on the size of the syringe used.

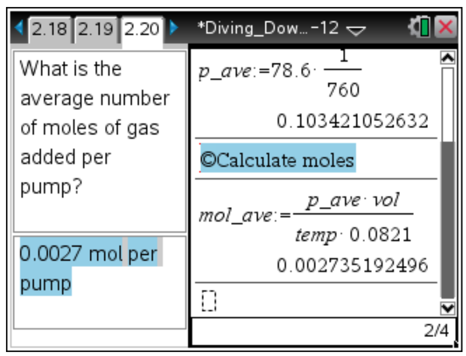




2.20 What is the average number of moles of gas added per pump?

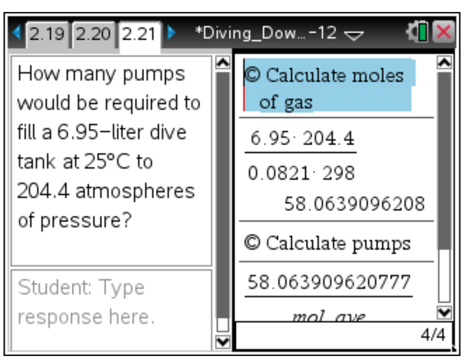
Moles will vary depending on the size of the syringe used.

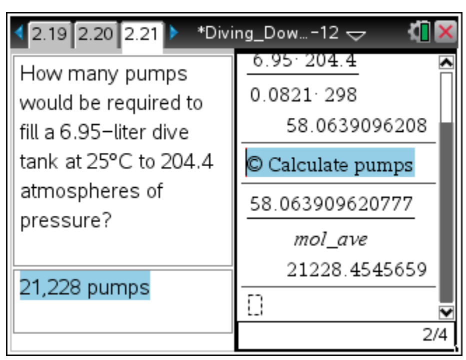




2.21 How many pumps would be required to fill a 6.95-liter dive tank at 25°C to 204.4 atmospheres of pressure?

Number of pumps will vary depending on the size of the syringe used.

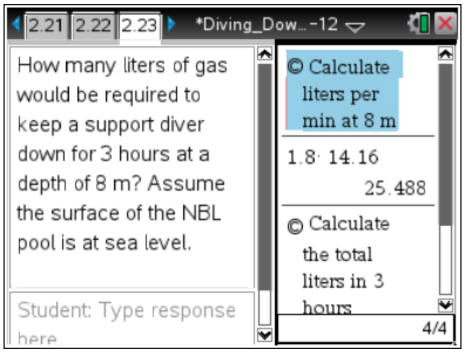


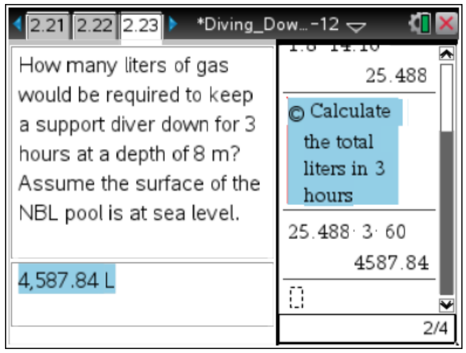


At sea level, 1 atmosphere of pressure is acting on our bodies. When diving in the NBL, for approximately every 10 meters of water depth, an additional atmosphere of pressure is acting on the diver. With a water temperature of 37°C in the NBL, a support diver consumes, on average, 14.16 liters of gas per minute for every atmosphere of pressure.

2.23 How many liters of gas would be required to keep a support diver down for 3 hours at a depth of 8 m? Assume the surface of the NBL pool is at sea level.

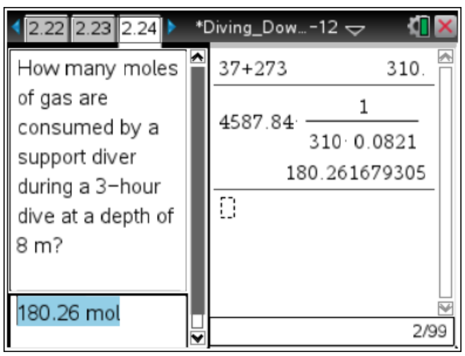
4,587.84 L





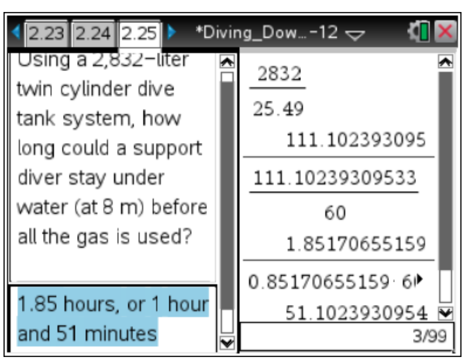
2.24 How many moles of gas are consumed by a support diver during a 3-hour dive at a depth of 8 m?

180.26 mol



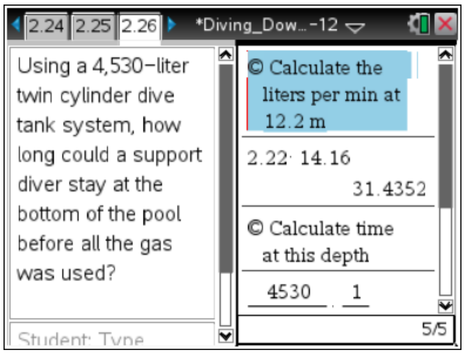
2.25 Using a 2,832-liter twin cylinder dive tank system, how long could a support diver stay under water (at 8 m) before all the gas is used?

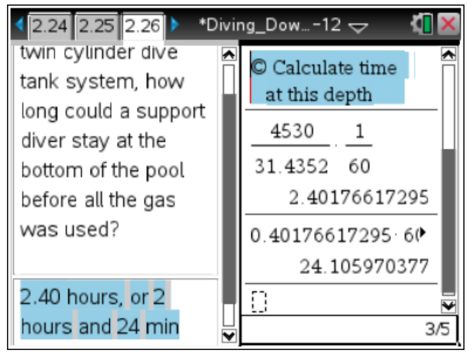
1.85 hours, or 1 hour and 51 minutes



2.26 Using a 4,530-liter twin cylinder dive tank system, how long could a support diver stay at the bottom of the pool before all the gas was used?

2.40 hours, or 2 hours and 24 minutes





2.27 Do the answers given in questions 2.25 and 2.26 give the maximum amount of time the support diver could stay at the depths listed? Explain your answer.

No, the maximum amount of time would be a little less than the answers found. The support diver would not be able to swim back to surface if all of the gas in the tanks was used.

Contributors

This problem was developed by the Human Research Program Education and Outreach (HRPEO) team with the help of NASA subject matter experts and high school AP Chemistry instructors.

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