611-2305 (30-172) - 611-2308 (30-174) Gay-Lussac's Law and Absolute Zero

Description:
The Gay-Lussac's Law and Absolute Zero apparatus is used to show the relationship of pressure to a temperature of a gas. This allows students to determine the value of absolute zero. The sealed temperature bulb is immersed in boiling water, ice water, room temperature water (ambient temperature), a salt-ice bath and a dry-ice bath. The corresponding temperature and pressure readings are recorded. A plot of pressure versus temperature allows for the extrapolation of absolute zero.

Warranty and Parts:
We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

How to Teach with Gay Lussac's Law and Absolute Zero:
Concepts Taught: Gay-Lussac's Law; Absolute Zero
Curriculum Fit: Physics Sequence; Pressure and Gases; Temperature and Gases; Kinetic Energy
Grades 6-8 and up.

Additional Materials Needed:
- Beakers—(5) 2,000 mL
- Thermometer (-100 to 100°C)
- Bunsen burner
- Support stand
- Wire gauze
- Sodium chloride (NaCl) [table salt or rock salt]
- Dry ice
- Stirring rod
- Universal clamp (recommended)
- Right angle clamp (recommended)
- Ring stand (recommended)
- Protective mitts for extreme temperatures (recommended)

Theory:
What is Gay-Lussac's Law?
What is Absolute Zero?
What is an ideal gas?

Safety Factors:
There is potential for injury when performing laboratory experiments. We recommend these safety precautions.
- All people in the lab should wear safety glasses when watching a demonstration or performing an experiment.
- Any individual lighting a Bunsen burner or dispensing dry ice should exercise caution as these items can cause burns. It is recommended that dry ice be handled with suitable gloves, such as protective mitts for extreme cold temperatures.
- Exercise care when transferring a glass thermometer from cold temperature bath to a hotter bath, as breakage may occur.
- The salt-ice bath contents upon reaching room temperature may be flushed down a sink using running water.
- Unused dry ice may be placed in a fume hood, so that it will sublime (i.e., change from a solid state to a gaseous state).

Experiment 1: Determination of Absolute Zero

Procedure:
1. Obtain a 2,000 mL beaker or a similar size and ensure that the bulb of the absolute zero apparatus fits easily into the beaker. If not, select a larger size and check the fit again. While one student supports the apparatus, another student should place a thermometer in the beaker alongside the bulb to ensure a comfortable fit for both pieces of laboratory equipment.
   Remove the absolute zero apparatus and the thermometer. Fill the beaker with tap water between 30 and 60°C. The beaker should be about 75% full. Check for overflow by submerging bulb. Observe the fluid level that will allow the bulb to be fully submerged. Apply this observation to future steps in the experiment.
2. The absolute zero apparatus should be clamped to a ring stand or supported in one's hand using the attached red handle. Do not lift the beaker of fluid to avoid spillage.

3. Lower the bulb of the apparatus into the beaker. Place the thermometer in the beaker and wait for the reading to stabilize. Record the value below. Wait for the pressure reading to stabilize and record its value to the nearest psi. If the needle of the pressure gauge sticks, tap the cover plate gently until the reading becomes stable.

   Pressure = ___________________________ psi

   Record the temperature in Celsius below.

   Temperature = ___________________________°C

   Repeat Step 3 two more times. Calculate the average value.
   Average Pressure = ____________________ psi
4. Fill a second beaker with water about 75% full and heat to boiling using a Bunsen burner.
5. Immerse the bulb of the absolute zero apparatus in the beaker. Place the thermometer in the beaker. Wait for the pressure and temperature readings to stabilize. Record the values obtained below.

   Pressure = __________________________ psi
   Temperature = ________________________________°C

   Repeat Step 6 two more times. Calculate the average value.

   Average Pressure = ___________________ psi
6. Fill a third beaker with water about 25% full. Add ice to the beaker along with water until the total volume is about 75% of the beaker's volume. Using a stirring rod, stir the ice/water mixture and allow the mixture to sit for about five minutes.
7. Immerse the bulb of the absolute zero apparatus in the beaker. Place the thermometer in the beaker. Wait for the pressure and temperature readings to stabilize. Record the values below.

   Pressure = __________________________ psi
   Temperature = ________________________________°C

   Repeat Step 7 two more times. Calculate the average value.

   Average Pressure = __________________ psi
8. Carefully pour the ice/water mixture from Step 7 into a fourth beaker. Add more ice if necessary, so that cubes are still visible. Begin adding sodium chloride to the mixture while stirring with a stirring rod. The volume of the mixture in the beaker should be about 75% of the total volume.
9. Immerse the bulb of the absolute zero apparatus in the beaker. Place the thermometer in the beaker. Wait for the pressure and temperature readings to stabilize. Record the values below.

   Pressure = __________________ psi
   Temperature = _______________________________°C

   Repeat Step 9 two more times. Calculate the average value.

   Average Pressure = __________________ psi
10. Using protective temperature mitts and safety goggles obtain a piece of dry ice and wrap it in an old towel or something similar. Smash the dry ice into smaller bits by hitting the wrapped towel with a mallet or by smashing the towel/dry ice against the floor. The dry ice should break into a powder. Carefully pour the dry ice powder into the fifth beaker.
11. Immerse the bulb of the absolute zero apparatus in the beaker. It may be necessary to smash more dry ice into a powder, so that the bulb is completely packed in powder. The temperature of the dry ice is about -78°C. Wait for the pressure reading to stabilize. Record its value to the nearest psi.

    Pressure = __________________ psi

12. Repeat Step 11 two more times. Calculate the average value.

    Average Pressure = __________________ psi
    Follow safety instructions for proper disposal of dry ice.

13. Graph the data obtained in Steps 1-12. You will have a graph of pressure versus temperature. The x-axis should run from -300°C to 150°C. The y-axis should run from -5 to 20 psi. By extrapolation you should be able to find the value of absolute zero on your graph. Record your experimental value below.

    Absolute Zero (experimental) = ___________________________°C

14. Find the percent difference between the experimental absolute zero value and the theoretical absolute zero value (-273°C). Use the equation below.

% Difference = $$\left[\frac{(truevalue - experimentalvalue)}{truevalue}\right] \times 100\%$$

% Difference = ________________________________

Questions:

1. Explain how the absolute zero apparatus along with the graph made in Step 16 above could be used to determine the temperature of a hot tub without the use of a thermometer.

____
____
____

2. How would methanol contamination of ambient water in Step 2 affect the results?

____
____
____

Application of Gay-Lussac's Law:

Gay Lussac's Law states that as the temperature of an enclosed gas increases, the pressure increases, if the volume is held constant. It is represented mathematically as follows:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

P_1 = Initial Pressure
T_1 = Initial Temperature
P_2 = Final Pressure
T_2 = Final Temperature

As an example, it is dangerous to incinerate or store aerosol containers above a certain temperature because as the temperature increases the pressure inside the can increases, too. The can represents a fixed volume, thus the can has the potential to explode if the temperature is too hot due to the increased kinetic energy of the particles. Warning labels to that effect can be found on many aerosol products, such as Lysol® and WD-40®.