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| **Lesson Title** | Lighters Don't Work When Wet |
| **Length of Lesson** | 1 hour 15 min |
| **Created By** | Chris Ruhs |
| **Subject** | Chemistry |
| **Grade Level** | 10-12$^{th}$ Grade |
| **State Standards** | Chemistry I: 10 b |
| **DOK Level** | DOK 2-3 |
| **DOK Application** | Students observe and think deeply about the ideal Gas Law. |
| **National Standards** | B (Physical Science) |
| **Graduate Research Element** | Understanding of the Ideal Gas Law underpins the dynamics of VOCs, is significant for GCMS work, and is generally needed for preparing chemical reactions. |

**Student Learning Goal:**
MS 9-12th Grade:
Chemistry I: 10 (b) Describe the relationship among volume, temperature, pressure, and moles using ideal gas laws. *Students will experience and deeply understand the Ideal Gas Law by measuring the temperature, pressure, volume, and mass of a gas.*

National Science Education Standards of Content 9-12:
B: Physical Science: Structure and Properties of Matter. *The concepts in this lesson plan are underpinned by the behavior of gases when temperature, pressure, volume, or mass is changed.*

**Materials Needed (supplies, hand-outs, resources):**
Laboratory worksheets, tubs, lighters, flasks, watch glasses, graduated cylinders, markers, thermometers, pressure gauge.

**Lesson Performance Task/Assessment:**
Formative:
1. Review of the ideal gas law with mathematical rearrangement of variables to solve for molecular weight.

Summative:
1. Place students into groups of foru.
2. Hand each group a laboratory worksheet.
3. Walk them through the laboratory procedures.
4. Give them time to complete the laboratory exercise, ask questions, and complete the worksheet.
5. Each group must:
    a. Weight a dry lighter
    b. Fill a tub with water

c. Fill a flask with water to the point of over-flowing.
d. Place a watch glass over the flask to create seal, then invert the flask without letting any water out, and submerge the top of the flask into the tub of water.
e. Collect 150-200 mL of butane from the lighter into the inverted flask.
f. Mark the gas/water interface with a marker.
g. Let the gas escape from the flask and fill the flask up with water to the marked line, making sure not to wash the mark away (if using soluble ink).
h. The amount of water in the flask represents the volume of gas that was collected from the light; measure this volume of water carefully in a graduated cylinder.
i. After the lighter has been dried very thoroughly, weigh the lighter; the difference between the initial mass and this final mass will be the mass of the gas released into the flask.
j. Measure the temperature of the water, since the gas will have equilibrated with it, and it will represent the temperature of the gas.
k. Read the air pressure from a pressure gauge, since the gas will have equilibrated with it, and it will represent the pressure of the gas.
l. Having now carefully measured the volume, mass, temperature, and pressure of the butane gas, solve for the molecular weight of the butane gas.
m. Compare that number with 58 g/mol, and calculate a percent error:

[ (theoretical – experimental)/ theoretical ] x 100

6. Review the experience to reinforce the connection between the formula written on the worksheet and physical ability to measure and calculate properties of real gases.

**Lesson Relevance to Performance Task and Students:**
An abstract and/or mathematical understanding of gas laws is useful for teaching students how to approach word problems relating to gases, however, students may not envision the reality of what the written problems signify. This activity-based lesson plan is designed to tie real-world scenarios and laboratory experience to their abstract understanding, so that the understanding is reinforced and robustly integrated/scaffolded.

**Anticipatory Set/Capture Interest:**
I asked the students if it was possible to measure the volume, temperature, pressure, and mass of a gas, and then solve for the molecular weight of the gas. When they responded, "yes", I asked them to prove it.

**Guided Practice:**
Review of gas laws.

**Independent Practice:**
Laboratory activity and worksheet completion.

**Remediation and/or Enrichment:**
Remediation:
Individual IEP.

Enrichment: Give the students an unknown gas, and ask them to tell you what the gas is without any help from you.

**Check(s) for Understanding:**
How would you explain the Ideal Gas Law to a 10 year old?
What is the formula of the Ideal Gas Law?
In what scenario could you apply this formula?

**Closure:**
Student-lead, teacher-guided review.

**Possible Alternate Subject Integrations:**
Environmental science: Atmosphere and climate change.

**Teacher Notes:**
The combination of group work and hands on laboratory activities reinforced the Ideal Gas Law as a practical and valuable truth. Students are left with a sense of accomplishment, since they are now able to accurately calculate the molar mass of an unknown gas.