**Lab 3.3 Temperature and Ideal Gases**

**Task 1.** A quad of concept questions.

1. Which has more molecules – a mole of nitrogen (N₂) gas or a mole of oxygen (O₂) gas?
   a. oxygen
   b. nitrogen
   c. both the same

2. Which weighs more – a mole of nitrogen (N₂) gas or a mole of oxygen (O₂) gas?
   a. oxygen
   b. nitrogen
   c. both the same

3. A plastic soda bottle is empty and sits out in the sun, heating the air inside. Now you put the cap on tightly and put the bottle in the fridge. What happens to the bottle as it cools?
   a. it expands and may burst
   b. it does not change
   c. it contracts and the sides collapse inward
   d. it is too dark in the fridge to tell

4. You put 1 kg of ice at 0°C together with 1 kg of water at 50°C. Lₕ = 80 cal/g  \( c_{\text{water}} = 1 \text{ cal/g°C} \)
   Calculate the heat needed to melt all the ice =
   Calculate the heat delivered by cooling the water from 50°C to 0°C =

   What is the final temperature?
   a. 0°C
   b. between 0°C and 25°C
   c. 25°C
   d. between 25°C and 50°C

**Task 2.** Ideal Gas Law vs. Van der Waals

Calculate the pressure exerted by 0.3 mol of helium in a 0.2 L container at -25 °C using:
\[ R = 0.0821 \text{ L·atm/mol·K} \]
\[ a_{\text{He}} = 0.0341 \text{ atm·L}^2/\text{mol}^2 \]
\[ b_{\text{He}} = 0.0237 \text{ L/mol} \]

A. Ideal gas law
   \[ p = \frac{nRT}{V} \]

B. van der Waal’s equation
   \[ \left(p + \frac{an^2}{V^2}\right)(V - nb) = nRT \quad \Rightarrow \quad p = \frac{nRT}{V - nb} - \frac{an^2}{V^2} = \]

Calculate the pressure if the container contained oxygen instead of helium.
\[ a_{\text{O₂}} = 1.364 \text{ atm·L}^2/\text{mol}^2 \]
\[ b_{\text{O₂}} = 0.0318 \text{ L/mol} \]

A. Ideal gas law
   \[ p = \frac{nRT}{V} \]

B. van der Waal’s equation
   \[ p = \frac{nRT}{V - nb} - \frac{an^2}{V^2} = \]
Task 3. Ideal Gas Law

Constant Temperature
- With the pressure coupling disconnected, push the plunger all the way in so that the stop is bottomed out. Note the volume reading on the syringe. It should be around 20 cc.
- Set the plunger for a volume of 60 cc. Connect the pressure coupling. Slowly compress the plunger and watch what happens to the temperature and pressure as the volume is reduced. Try to compress slowly enough to prevent substantial changes in temperature.
- After the plunger has gone all the way down, release and allow it to expand back out on its own.
- From the graphs, record the pressure and volume at points of constant temperature.

<table>
<thead>
<tr>
<th>State</th>
<th>Volume (cc)</th>
<th>Pressure (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60.0</td>
<td></td>
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<tr>
<td>2</td>
<td></td>
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</tbody>
</table>

- For constant temperature, the Ideal Gas Law reduces to \( P_1 V_1 = P_2 V_2 \), or \( \frac{V_1}{V_2} = \frac{P_2}{P_1} \). Are the ratios equal? Why or why not?

Varying Temperature
- Record the starting volume (from the concluding step of the previous setup it should be close to 60 cc)
- While firmly holding the base of the apparatus, quickly compress the plunger so that the stop is bottomed out.
- Hold this position until the temperature and pressure have equalized and are no longer changing. It should take less than 30 seconds for the temperature to return to room temperature.
- Release the plunger and allow it to expand back out on its own. (It may not go back to 60 cc.) Wait again until the temperature and pressure have equalized and are no longer changing.

<table>
<thead>
<tr>
<th>State</th>
<th>Pressure</th>
<th>Volume</th>
<th>Temperature</th>
<th>pV/T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before compression</td>
<td></td>
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<tr>
<td>Maximum temperature (pick the point where the temperature has peaked, not the pressure. It takes the temperature sensor about an additional 1/2 second to respond.)</td>
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<tr>
<td>After compression; temperature has stabilized</td>
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<tr>
<td>After release, final volume reading on the syringe</td>
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Questions
1. When the syringe volume is suddenly compressed, why does the pressure momentarily spike?
2. When the plunger is released in the last part of the data run, what happens to the temperature? Why?

Task 4. Engine Combustion
- At the beginning of a compression stroke the cylinder in a combustion engine contains 1.0 L of air at atmospheric pressure and a temperature of 20°C. At the end of the stroke the air has been compressed to a volume of 60 cm³ and the absolute pressure is 35 atm. What is the temperature of the compressed air?
- Illustrate this with the rapid compression of air in a cylinder using the fire syringe. What would happen if you slowly compressed the cylinder; would the temperature still rise as fast?