**LAB 1: Density of Gases and Liquid**

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Section A

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**Summary**

In this lab, we are measuring density of gases and liquids, which is the mass over volume. In the first part, we will measure the pressure and temperature of nitrogen using a pressure transducer. Using ideal gas law, we can get the volume and mass of the gas to find the density. In the second part, we will be given a graduated cylinder and a scale to measure the volume and mass, respectively, and find the density.

**Procedure**Please refer to MECH2 course page.

**Results**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Data and Calculations |  |  |  |  |  |  |  |
|  | Total mass (V) | Total mass (kg) | Pressure (V) | Pressure (Psi) | Temperature (K) | **R-nitrogen (J/kgK)** | **Density (kg/m^3)** |
| Empty tank/atm pressure | 3.649 | 10.586 | N/A |  |  |  |  |
| 100~200 psi | 3.650 | 10.589 | 1.477 | 133.046 | 295.300 | **4052.887** | **0.766** |
| Hot bath | 3.650 | 10.589 | 1.555 | 140.690 | 311.200 | **4066.772** | **0.766** |
| Cold bath | 3.650 | 10.589 | 1.429 | 128.342 | 283.700 | **4069.449** | **0.766** |
| ~400 psi - cold | 3.660 | 10.618 | 3.827 | 363.346 | 282.700 | **1051.061** | **8.431** |
| 400 psi - hot | 3.660 | 10.618 | 4.174 | 397.352 | 307.200 | **1057.761** | **8.431** |
| *Hot water* | *318.2 K* |  |  |  |  |  |  |

Table 1: Data and Calculations (bolded) of Lab 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Measurements and Calculations |  |  |  |  |  |
|  | Temperature (C) | Cylinder mass (g) | Total mass (g) | Volume (ml) | **Density (kg/m^3)** |
| Water | 19.00 | 198.00 | 671.00 | 475.00 | **995.79** |
| Water | 36.00 | 214.00 | 833.00 | 620.00 | **998.39** |
| Water in saturated salt | 20.00 | 198.00 | 752.00 | 520.00 | **1065.38** |
| Canola oil | 10.00 | 177.00 | 638.00 | 510.00 | **903.92** |
| Maple syrup | 10.00 | 215.00 | 618.00 | 296.00 | **1361.49** |

Table 2: Data and Calculation (bolded) of Lab 2

|  |  |  |
| --- | --- | --- |
| *Pressure Transducer* |  |  |
| Given | Pressure (Psi) | Set up #4 (V) |
|  | 0 | 0.119 |
|  | 400 | 4.2 |
| *From Interpolation* |  |  |
| Slope | 98 | psi/V |
| Y-intercept | -11.7 | psi/V |
| *Mass to Voltage Scale Factor* | |  |
| 20 | kg |  |
| 6.894 | V |  |
| *Volume of Tank* |  |  |
| 0.003785 | m^3 |  |
| *Miscellaneous Constant(s)* |  |  |
| psi to Pa | 6894.75729 | Pa/psi |

Table 3: Other Constants and Given Values Used in the Lab

**Questions**

*1. Compute the gas constant, R, for N2 based on your data from Part 1. Compare your*

*result to the expected value found in your Thermodynamics textbook.*

According to our textbook (Appendix 1, Table A-1), the R value of Nitrogen gas at STP is 0.2968 kJ/kgK, or 269.8 J/kgK. Our calculations (Table 1) shows the R value at about 4000 and 1000 J/kgK, about one order of magnitude higher than the theoretical value. While the theoretical values and our experimental values vary, the order of magnitude makes sense. Since:

And our pressures at about 135 psi and 370 psi, respectively, are one order of magnitude higher than STP at 14.7 psi, it is sensible that RNitrogen and P are linearly dependent to the same order of magnitude.

*2.*

*Estimate how close the measured values of R are to the “true values”. To do this, you*

*will need to perform an error analysis. See the information provided in Appendix A. The*

*following information regarding the accuracy of the instrument has been provided by the*

*manufacturers (at 99.7% “confidence level”, that is 3 standard deviations):*

*∆P = ±3%*

*∆V = ±1%*

*∆m = ±1g*

*∆T = ±3K*

*3.*

*Apart from inaccuracy due to the measurement instruments, what are the sources of*

*error in the gas density measurement experiment? What could be done to improve the accuracy of the results?*

Sources of error:

1. When measuring the mass of the cylinder, the cylinder was oscillating while hanging which changed the voltage values
2. For cold/hot cases the change in temperature after the cylinder is extracted from the water is not accounted for.

*4. Liquid density can be measured with a graduated cylinder or a densitometer. Explain why the densitometer is more accurate (hint: it will be helpful to analyze the hydrostatics that relate the floating height to density).*

The hydrometer measures the specific gravity of a liquid i.e. it measures the ratio of the density of the liquid to the density of water. It is used by dropping the hydrometer into water and recording where the surface of the water lines up. This approach introduces some sources of error:

1. The liquid needs to be stagnant. Any turbulence gives an erroneous answer
2. Gravity is not constant everywhere on Earth

A densitometer works by having light shine on the surface and measuring the darkness of the object. This approach is independent of any turbulence, gravity and removes any human error since the approach is completely digitised.

*5.Estimate the accuracy of the liquid density measurements. Compare these results to those for the gas density measurement and explain the reason for differences (if any).*

**Appendix A**

Error calculations

Uncertainty general equation: (σP)^2=(∂P/∂V)^2 (σV)^2+(∂P/∂I)^2 (σI)^2