Temperature and Pressure Measurements of an Ideal Gas That Is Heated in a Closed Container

INTRODUCTION

This report discusses an experiment to study the relationship of temperature and pressure of an ideal gas (air) that was heated in a closed container. Because the ideal gas was in a closed container, its volume remained constant. The objective of the experiment is to test whether the ideal equation of state holds. In the equation,

$$pV = mRT,$$

where p is the pressure the gas, V is the volume, m is the mass, R is a constant, and T is temperature. This report presents the procedures for the experiment, the experiment's results, and an analysis of those results.

PROCEDURES

In this experiment, air (an ideal gas) was heated in a pressure vessel with a volume of 1 liter. Attached to this pressure vessel was a pressure transducer and thermocouple to measure the pressure and the temperature, respectively, of the air inside the vessel. Both of these transducers produced voltage signals (in Volts) that were calibrated to the pressure (kPa) and temperature (K) of the air (the atmospheric pressure for where the experiment occurred is assumed to be 13.6 psia). In addition, the theoretical temperature (K) of air was calculated as a function of the measured pressured values (kPa).

RESULTS AND DISCUSSION

This section analyses the results of the experiment. The experiment went as expected with no unusual events that would have introduced error. The voltages as measured for the pressure and temperature transducers appear in Table A-1 of the Appendix. Also included in the Appendix are the equations used for calibrating those voltages with the actual pressures and temperatures. These equations led to the values of pressure and temperature that are shown the third and fourth columns of Table A-1. From these values, a graph between temperature (K) and pressure (kPa) was created (Figure A-1). As can be seen from the graph, the

relationship of temperature versus pressure is roughly linear.

As part of this experiment, the theoretical values of temperature were calculated for each measured pressure value. In this calculation, which used the ideal gas equation, the volume and mass were assumed to be constant. These theoretical values of temperature are shown in the final column of Table A-1. From this final column arose Figure A-2, a graph of ideal temperature (K) versus pressure (kPa). As shown in this graph, the relationship between temperature and pressure is exactly linear.

A comparison between the graph showing measured data (Figure A-1) and the graph showing theoretical data (Figure A-2) reveals differences. In general, the measured values of temperature are lower than the ideal values, and the measured values are not exactly linear. Several errors could explain the differences: precision errors in the pressure transducer and the thermocouple; bias errors in the calibration curve for the pressure transducer and the thermocouple; and imprecision in the atmospheric pressure assumed for the locale. The bias errors might arise from the large temperature range considered. Given that the temperature and pressure ranges are large, the calibration equations between the voltage signals and the actual temperatures and pressures might not be precise for that entire range. The last type of error mentioned, the error in the atmospheric error for the locale where the experiment occurred is a bias error that could be quite significant, depending on the difference in conditions between the time of the experiment and the time that the reference measurement was made.

CONCLUSION

Overall, the experiment succeeded in showing that temperature and pressure for an ideal gas at constant volume and mass follow the relation of the ideal gas equation. Differences existed in the experimental graph of temperature versus and pressure and the theoretical curve of temperature versus pressure. These differences, however, can be accounted for by experimental error.

Appendix: Experimental Data and Plots

This appendix presents the data, calculations, and graphs from the experiment to verify the ideal gas equation. The first two columns of Table A-1 show the measured voltages from the pressure transducer and the temperature transducer. Column three shows the measured values of pressures calculated from the following calibration curve for the pressure transducer:

$$p = 4.3087(V \cdot V) - 13.1176V + 10.7276$$

where V equals the voltage output (volts) from pressure transducer, and p equals the absolute pressure (kPa). Column four presents the measured values of temperature (K) calculated from the calibration curve for the thermocouple:

$$T = Tref + V/S$$

where Tref equals the ice bath reference temperature (0°C), V equals the voltage (volts) measured across the thermocouple pair, and S equals the thermocouple constant, 42.4 µV/°C. Finally, column 5 presents the ideal values of temperature for the corresponding measured values of pressure. These ideal values arise from the ideal gas equation (PV=mrt). Figure A-1 shows the graph of temperature (K) versus pressure (kPa) for the measured case. Figure A-2 shows the graph of temperature versus pressure for the ideal case.

Table A-1.Data From Experiment

Voltagepres(V)	Voltagetemp(V)	Pressuremeas(kPa)	Temperaturemeas(K)	Temperatureideal(K)
6.32	0.0011	99.90	298.94	312.17
6.39	0.0020	102.81	320.32	321.28
6.78	0.0031	119.82	346.26	374.44
7.31	0.0046	145.04	381.64	453.24
7.17	0.0052	138.14	395.79	431.69
7.35	0.0064	147.04	424.09	459.50

7.45	0.0073	152.11	445.32	475.32
7.56	0.0078	157.78	457.11	493.04
7.66	0.0097	163.02	501.92	509.43
8.06	0.0107	184.86	525.51	577.69
8.10	0.0114	187.12	542.02	584.75
8.34	0.0130	200.97	579.75	628.03

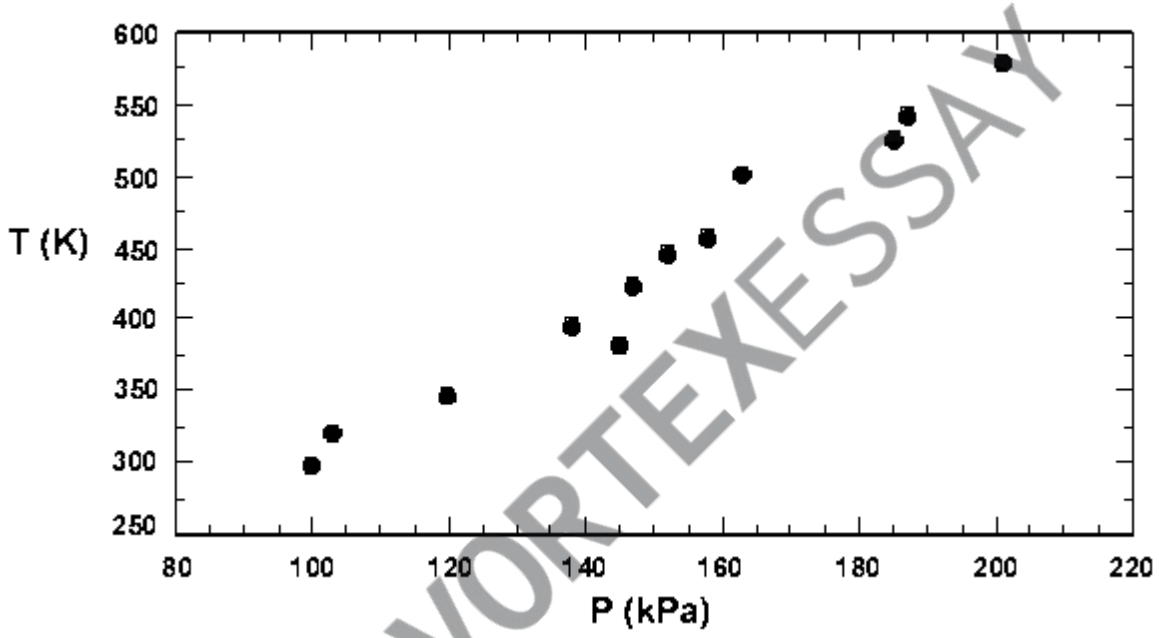

Figure A-1. *Temperature versus pressure, as measured by the transducers*

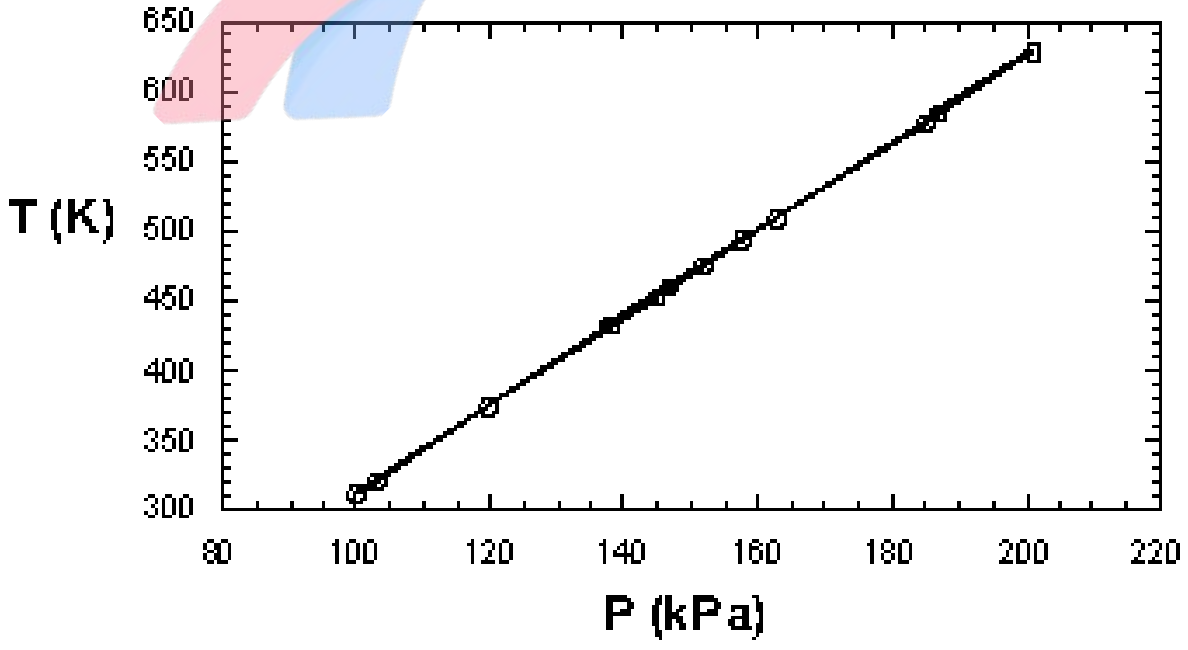

Figure A-2. *Temperature versus pressure, as calculated from the ideal gas equation.*