# Lab 3: Ideal Gas Law

Graded

**Student**

Fady Youssef

**Total Points**

**73 / 97 pts**

**Question 1**

## Part 1 Data Tables

**8** / 10 pts

**– 0 pts** Correct

**– 2 pts** Point adjustment

1 These appear to be the pressures with the atm pressure added in. This is accurate, but it's best to have the actual number recorded from the instrument, not adjusted, on your data table, and a second column for absolute pressure. (-2)

**Question 2**

## Plots

**13** / 14 pts

**– 0 pts** Correct

**– 1 pt** Point adjustment

2 Include apparatus in titles (-1)

**Question 3**

## Four-line and two-line summaries

**14** / 18 pts

**– 0 pts** Correct

**– 4 pts** Point adjustment

3 4.8 +/- 0.4 (-2)

4 remember that when there is a 1, take two digits. 3.95 +/- 0.19 (-2)

**Question 4**

## Questions

**15** / 15 pts

✔ **– 0 pts** Correct

5 Awesome

Question 5

## Error analysis

10 / 15 pts

**– 0 pts** Correct

**– 5 pts** Point adjustment

6 You had no evidence of systematic error because your values for the y-intercept agreed with the accepted value in both cases. -4

7 No, this was due to different amounts of air present in the two apparatuses.

8 Thermometer? -1

9 No, this was not a source of error. This was expected.

Question 6

## Challenge

13 / 25 pts

**– 0 pts** Correct

**– 12 pts** Point adjustment

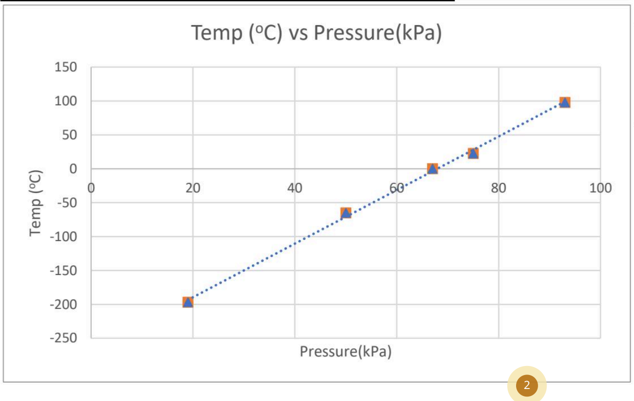
10 13/15

11 More explanation needed for how you conducted your original calculation.

Questions assigned to the following page: 1, 2, and 3

Gas Apparatus 1:

| Bath | Pressure (kPa) | Temperature °C |
|---|---|---|
| Room Temp. (None) | 75 | 22.7 |
| Boiling water | 93 | 97.9 |
| Ice Water | 67 | 0.1 |
| Dry Ice/Alcohol | 50 | -65 |
| Liquid Nitrogen | 19 | -197 |



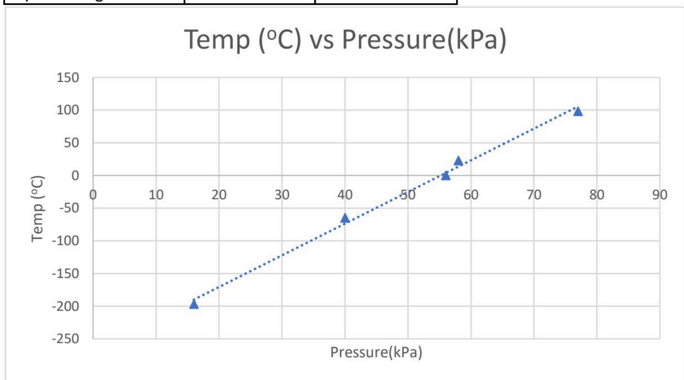

| | Slope (°C/KPa) | y-int °C |
|---|---|---|
| Mean | 3.951840295 | -268.53189 |
| SE | 0.098040404 | 6.447451848 |
| AE | 0.192159192 | 12.63700562 |

y-int(°C)
Results: -269 +/- 13
Range: -282 to -256
Expected: -273.15
Agree: YES

Slope (°C/KPa)
Result: 4 +/- .2
Range: 3.8 to 4.2

Gas Apparatus 2:

| Bath | Pressure (kPa) | Temperature °C |
|---|---|---|
| Room Temp. (None) | 58 | 22.7 |
| Boiling water | 77 | 98.2 |
| Ice Water | 56 | 0.1 |
| Dry Ice/Alcohol | 40 | -65 |
| Liquid Nitrogen | 16 | -197 |




| | Slope (°C/KPa) | y-int °C |
|---|---|---|
| Mean | 4.8468702 | -267.6353879 |
| SE | 0.210716627 | 11.26299587 |
| AE | 0.413004588 | 22.07547191 |

y-int(°C)
Results: -270 +/- 20
Range: -290 to -50
Expected: -273.15
Agree: YES

Slope (°C/KPa)
Result: 4.9 +/- .4
Range: 4.5 to 5.3

Question assigned to the following page: 4

Questions:

1. The boiling water bath is not 100°C because water boils when its vapor pressure matches the air pressure around it. Since Spokane is at a higher elevation, the air pressure is always lower than 1 atmosphere (101.3 kPa). With less air pushing down on the water, it takes less energy for the water molecules to escape as vapor. This means water does not need to reach 100°C to boil and instead boils at a lower temperature, around 98°C. The lower outdoor air pressure in Spokane is directly responsible for this change in boiling point, just like how water boils at even lower temperatures at higher elevations.

2. The gas density does not change because the apparatus is sealed, meaning no gas can go in or out. Density depends on the amount of gas and the space it takes up. Since both stay the same, the density does not change. Temperature affects pressure, but it does not change the amount of gas inside, so the density stays constant.

3. Humid air is air that has water vapor mixed in. When it moves into a cool or cold place, some of the water vapor turns into liquid or ice. If the air in the gas apparatus was very humid at room temperature, some of this water would condense as the temperature drops. This would remove some of the gas, causing the pressure to be lower than expected. Based on the Excel sheet, the pressure readings at lower temperatures would be affected because the condensed water takes away gas molecules, making the recorded pressures lower than they should be.

Question assigned to the following page: 5

Error Analysis Worksheet:

1. 
   - Reading gas apparatus gauge (+/- .2 KPa)

2. A definite source of random error in this lab came from the pressure gauge fluctuations during the lab, likely giving up small variations due to the slight movements, coupled with the reading error of the gauge gave us a source of random error. Another source of random error could've come from how the gas apparatus is held. Holding the apparatus leveled while trying to read the gauge head on is difficult, leading to slight movement in several directions while trying to read the gauge, possibly giving us minor variations in pressure readings while recording our measurements. Similarly, the temperature probe in the water baths but also the multimeter used in the alcohol seemed to have at least +/- 1°C error as it was fluctuating possibly due to the probe positioning leading to slight inconsistencies in the temperature readings.

3. Based on the experimental results, there is evidence of systematic error due to consistent differences in pressure readings between gas apparatuses. When we switched apparatuses, the pressure values were noticeably lower, showing a calibration issue. Also, the boiling water bath did not reach 100°C because of Spokane's lower air pressure, which affected the expected readings. Since these factors affected all trials, there is strong evidence of systematic error throughout the lab, leading to lower recorded pressure values.

4. The most likely sources of systematic error in this lab come from differences in gas apparatus calibration and environmental conditions. When we switched apparatuses, we noticed a consistent drop in pressure readings, showing that the devices were not calibrated the same. For example, at room temperature (22.7°C), the first apparatus recorded 75 kPa, while the second recorded only 58 kPa. In the boiling water bath, the first apparatus measured 93 kPa at 97.9°C, while the second recorded only 77 kPa at 98.2°C. This suggests that each apparatus had small but consistent shifts in pressure values, likely due to slight differences in internal volume or gauge calibration. Another source of systematic error is that the boiling water bath did not reach exactly 100°C because Spokane's air pressure is lower than 1 atmosphere. Since the ideal gas law equation $PV=nRT$ assumes standard boiling conditions, the lower boiling temperature causes lower pressure readings, shifting results slightly below theoretical values. Both of these factors affected all trials in the same way, confirming the presence of systematic error throughout the experiment.

Question assigned to the following page: 6

Challenge:

the bath with a thermometer and record the temperature ... you have made your determination, your instructor will compare the thermometer value to your calculated value.

**Scoring**: You will receive points based on the accuracy of your calculated value as follows:

| | |
|---|---|
| 25 points awarded | $\rightarrow$ within $\pm 5.0$°C |
| 20 points awarded | $\rightarrow$ within $\pm 10.0$°C |
| 15 points awarded | $\rightarrow$ within $\pm 15.0$°C |
| 10 points awarded | $\rightarrow$ within $\pm 20.0$°C |
| 5 points awarded | $\rightarrow$ within $\pm 25.0$°C |

Room Temperature Pressure: -36 kPa

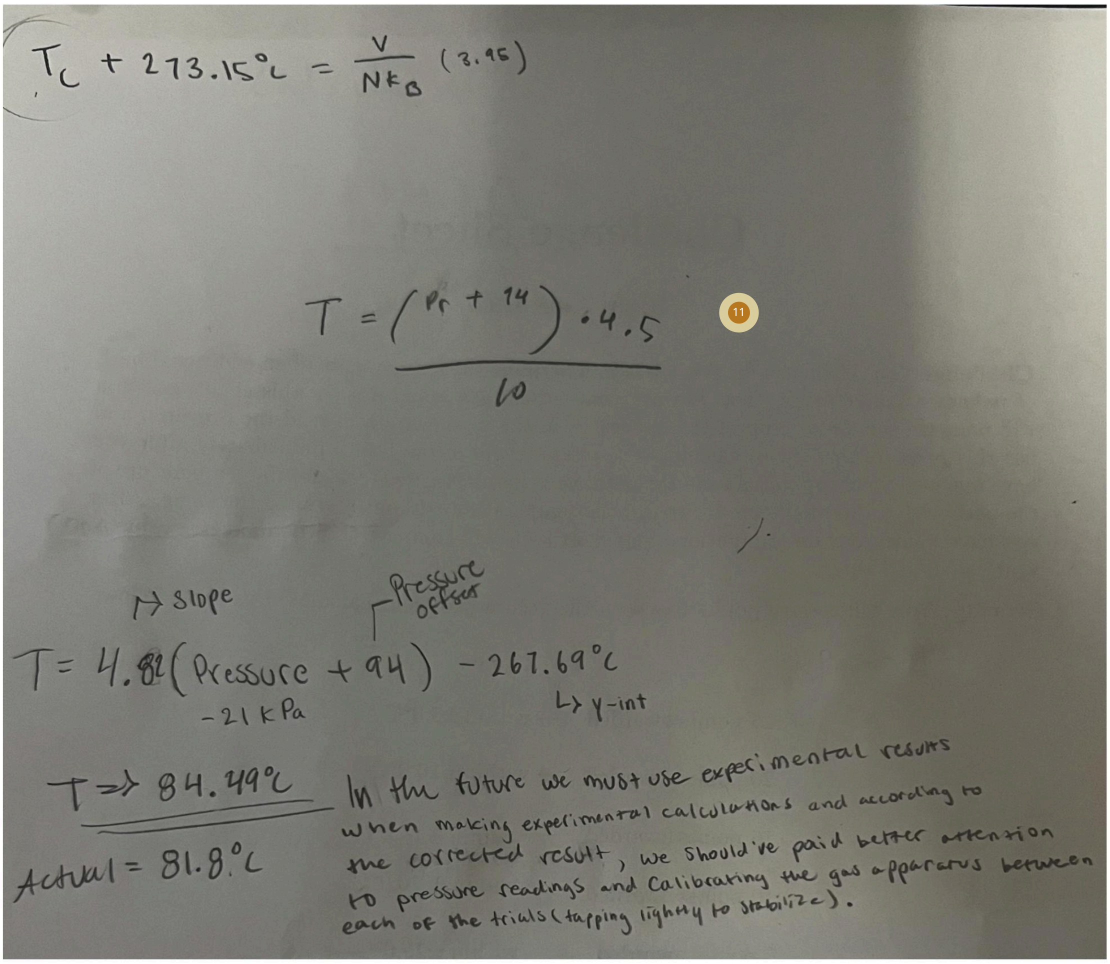
Final Pressure: -21 kPa

Predicted Temp.: 33.1°C

Thermometer Reading: 81.8°C

Points: 0

No questions assigned to the following page.



$$T_C + 273.15°C = \frac{V}{Nk_B} \; (3.95)$$

$$T = \frac{(P_r + 94) \cdot 4.5}{10}$$

$$T = \underbrace{4.82}_{\text{slope}}(\underbrace{\text{Pressure}}_{-21\,kPa} + \underbrace{94}_{\text{Pressure offset}}) \underbrace{- 267.69°C}_{\text{y-int}}$$

$T \Rightarrow 84.49°C$

Actual $= 81.8°C$

In the future we must use experimental results when making experimental calculations and according to the corrected result, we should've paid better attention to pressure readings and Calibrating the gas apparatus between each of the trials (tapping lightly to stabilize).

(Note in photo above: In the future we must use experimental results when making experimental calculations and according to the corrected results, we should've paid better attention to the pressure readings and calibrating the gas apparatus between each trial (tapping lightly to stabilize).)

The challenge was figuring out how to use Equation 6 with the given pressure and slope in a way that made sense. The key was realizing the pressure readings were relative, so we had to add 94 kPa to get absolute pressure. The corrected equation used a better slope (4.82) and intercept (-267.69°C) based on actual data, making it more accurate. Once we made these adjustments with the help of Dr. Fink, our calculation was much closer to the real temperature, showing that calibration and correct adjustments, along with improper chain of thought were the main issues.