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Quiz Section AG

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CHEM 142 Experiment #1: Atomic Emission

Goals of this lab:

- Utilize a variety of instruments to take measurements of the atomic emission of hydrogen gas.
- Analyze the results from different measurement devices.
- Calculate the percent error of your measured values from known literature values
- Evaluate the different measurements and results and compare the advantages and disadvantages of each approach.
- Using experimentally-determined values, predict future possible observations. Test the accuracy of these predictions and compare predicted values to observed results.
- Apply the concepts of atomic emission to the task of identifying unknown compounds.
- Appraise the accuracy of flame tests versus other identification methods. Recommend possible alternative methods for identifying unknowns. Defend this recommendation.

Your lab report will be graded on the following criteria using a poor/good/excellent rating system (see the Self-Assessment on the "Reporting Your Results for Exp #1" page of the lab website for more details):

- All calculations are clear and accurate, with proper use of significant figures, units, etc.
- Observations made in lab are careful and accurate. Unexpected or unusual results are repeated to ensure accuracy.
- Evaluations of measurement approaches are clear, well-structured, and supported with clear and reasonable arguments.
- Predictions and unknown identifications in the lab are reasonable given data gathered.
- The lab report is completed neatly with calculations shown in detail.

By signing below, you certify that you have not falsified data, that you have not plagiarized any part of this lab report, and that all calculations and responses other than the reporting of raw data are your own independent work. Failure to sign this declaration will result in 5 points being deducted from your lab score.

Signature: Emily Dong

*This lab is worth 60 points: 10 points for notebook pages, 50 points for the lab report
(Do NOT include your notebook pages when you scan your report for upload into Gradescope.)*

NAME Emily (Yunqi) DongQuiz Section AG**Part I.A.: Qualitative Observations and Spectroscope Measurements**

1. Neatly transfer the data from your notebook to Table 1-1 for the three spectral lines of longest wavelength. Look carefully to see as many spectral lines as possible and record the wavelength, color, and qualitative intensity (dim, bright, very bright, etc.) of each line. You will complete the fourth column after Question 4.

Table 1-1. Hydrogen lamp emission lines from a spectroscope.

Color of hydrogen lamp emission	Wavelength (nm)	Intensity (how bright?)	Calculated R_H value (m^{-1})
Green Blue	490	Bright	1.09×10^7
Red	655	very Bright	1.10×10^7
purple	435	Dim	1.09×10^7

2. In Table 1-1, which electron transition (give the wavelength) represents the smallest change in energy? How do you know?

Red. It is transferred from $n = 3$ to $n = 2$, which has the smallest state change of energy among all. (Blue is from 4 to 2, purple is from 5 to 2)

3. Since the hydrogen atomic emission lines that appear in the visible region of the spectrum represent a $n_f = 2$, what transition does your answer to #2 represent (show as $n_i \rightarrow n_f$)?

$3 \rightarrow 2$

4. Using your data from Table 1-1 for the longest wavelength, calculate R_H (the Rydberg constant for hydrogen) in units of m^{-1} . Show your calculation clearly with correct units and significant figures.

$$\begin{aligned} \frac{1}{\lambda} &= -R_H \left(\frac{1}{n_i^2} \right) + \left(\frac{R_H}{n_f^2} \right) \\ \frac{1}{\lambda} &= R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \\ R_H &= \frac{1}{\lambda \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)} \end{aligned}$$

$$\begin{aligned} R_H &= \frac{1}{655 \text{ nm} \times 10^{-9} \times \left(\frac{1}{2^2} - \frac{1}{3^2} \right)} \\ &= \frac{1}{655 \text{ nm} \times 10^{-9} \times \left(\frac{1}{4} - \frac{1}{9} \right)} \\ &= 1.10 \times 10^7 \text{ m}^{-1} \end{aligned}$$

5. Using the same type of calculation as in #4, complete the fourth column in Table 1-1. Find the average value of R_H from the data in Table 1-1.

Average R_H value from spectroscope measurements:

$$1.09 \times 10^7 \text{ m}^{-1}$$

NAME Emily DongQuiz Section A6**Part I.B: Spectrophotometer Measurements of Hydrogen Emission and the Balmer-Rydberg equation**

6. Now that we have an experimentally determined value for R_H , we can predict other emission lines that we were not able to observe with the limited scale of the spectroscope. For hydrogen, predict the wavelength (in nm) of the next unobserved transition.

$$n_f = 6, \quad n_i = 2$$

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = 1.09 \times 10^7 \text{ m}^{-1} \times \left(\frac{1}{4} - \frac{1}{36} \right)$$

$$\frac{1}{\lambda} = 1.09 \times 10^7 \text{ m}^{-1} \times \frac{8}{36}$$

$$\lambda = \frac{9}{2} \times \frac{1}{1.09 \times 10^7 \text{ m}^{-1}} = 4.13 \times 10^{-7} \text{ m}$$

$= 413 \text{ nm}$

7. Once you have calculated your predicted wavelength, check with your TA to see if you are on the right track. Your TA should initial your report before you continue with the rest of Part I.

TA initials: 

Let us now see if our calculations match experiment! Go back to the lab manual and complete the requested measurements.

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8. Neatly transfer the wavelength (λ) data from your notebook to Table 1-2, identify the n_i values, and provide the requested calculation results (all in decimal form, e.g., 1.25 instead of $1\frac{1}{4}$, with 3 sig figs). In your lab notebook, show your calculations for $\frac{1}{\lambda}$ and $\frac{1}{n_i^2}$ for the longest recorded wavelength. (Hint: for ease of plotting the data in Q13 provide the results of your $1/\lambda$ calculations with units of " $\times 10^{-3} \text{ nm}^{-1}$ ".)

Table 1-2. Hydrogen lamp emission lines from a USB spectrometer.

$\lambda \text{ (nm)}$	n_i	$\frac{1}{\lambda} (\times 10^{-3} \text{ nm}^{-1})$	$\frac{1}{n_i^2}$
409.40	6	2.44	2.78×10^{-2}
432.80	5	2.31	4.00×10^{-2}
485.70	4	2.06	6.25×10^{-2}
661.90	3	1.51	0.111×10^{-1}

9. Does your wavelength prediction in Q6 match the experimental data you recorded?

No. It has a difference of 3.6 nm, but it is very close.

10. The literature value for the longest visible-region spectral line for hydrogen is 656.3 nm. Calculate the percent error for your longest wavelength emission line for hydrogen recorded using the spectroscope and using the USB spectrophotometer.

$$\% \text{ error} = \frac{|x_{\text{measured}} - x_{\text{literature}}|}{x_{\text{literature}}} \times 100$$

Spectroscope	Spectrometer
$\% \text{ error} = \frac{ 655 \text{ nm} - 656.3 \text{ nm} }{656.3 \text{ nm}} \times 100$ $= 0.198\%$	$\% \text{ error} = \frac{ 661.90 \text{ nm} - 656.3 \text{ nm} }{656.3 \text{ nm}} \times 100$ $= 0.8533\%$

11. Compare the two % error values you calculated in Q10 and give a reasonable explanation for any differences. Discuss, specifically, how the instruments you use differ in terms of accuracy.

The % error of the spectroscope is lower than the one of the spectrometer. It may be caused by the fact that the spectroscope is harder for us to select certain point at the middle of the peak, causing the error to be larger.

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12. In Q4, you used the known n_f value and one of the recorded data points to determine the value of the Rydberg constant, R_H . Another approach would be to rearrange the Balmer-Rydberg equation into the equation of a line ($y = mx + b$) such that all of the wavelengths you recorded and the corresponding n_i values can be used to determine the value of R_H rather than relying on a single data point.

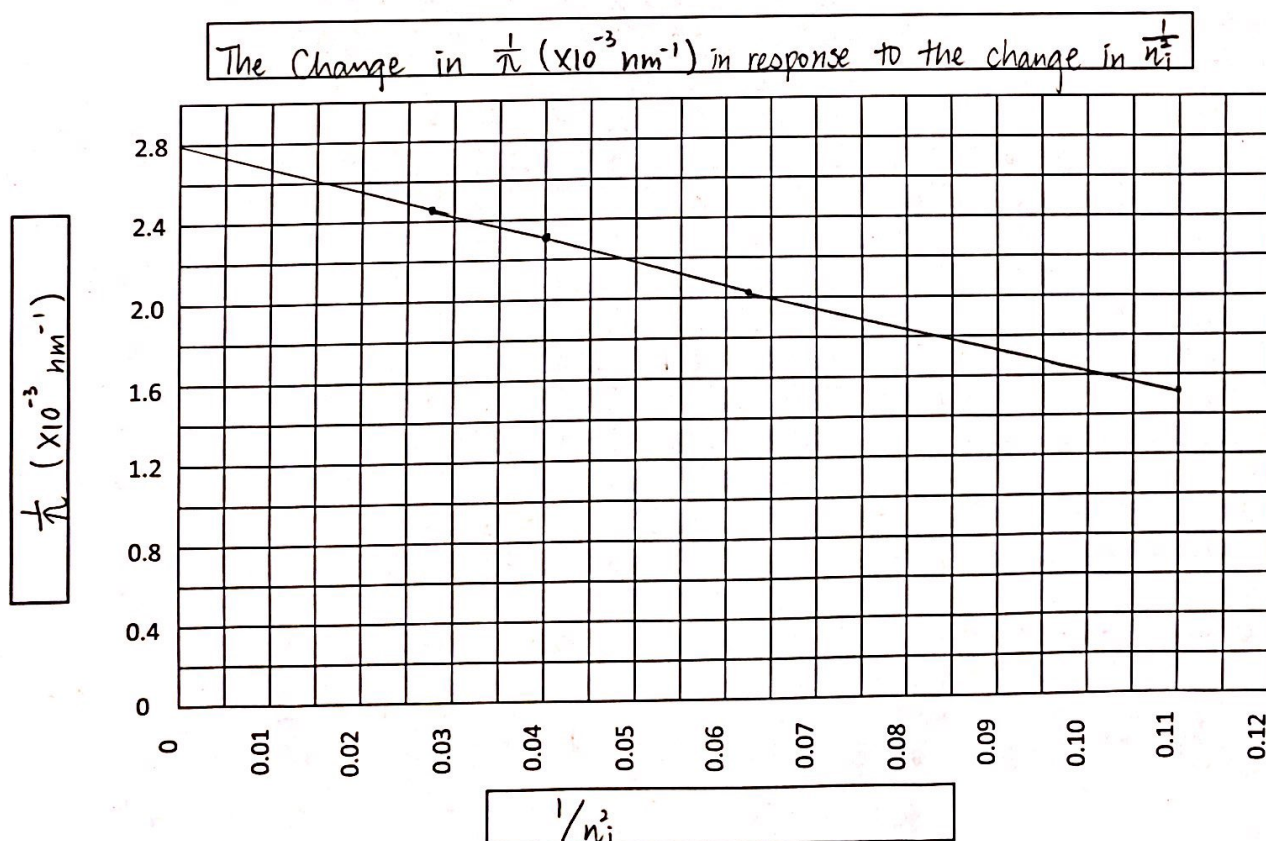
$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = -R_H \left(\frac{1}{n_i^2} \right) + \frac{R_H}{n_f^2}$$

Provide expressions for the data plotted on each axis, as well as the slope and y-intercept, both of which can be used independently to calculate the value of the Rydberg constant.

y-axis: $\frac{1}{\lambda}$ x-axis: $\frac{1}{n_i^2}$ slope: $-R_H$ y-intercept: $\frac{R_H}{n_f^2}$

13. Now plot your data from Table 1-2 using the graph paper below (use a straight-edge or ruler!). In the boxes provided, be sure to clearly label your axes and title the plot.



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14. Graphically determine the slope and y-intercept of your hand-drawn plot. (Remember: *slope = rise/run*). Calculate R_H (in m^{-1}) from the graphically determined slope and y-intercept. Show your data and calculations.

Graphically-determined slope: $\frac{\Delta y}{\Delta x} = \frac{2.31 - 2.44}{0.04 - 0.0278} = \frac{-0.13}{0.0122} = -10.7 (\times 10^{-3} \text{ nm}^{-1})$

Graphically-determined y-intercept: $2.8 (\times 10^{-3} \text{ nm}^{-1})$

R_H from the slope:

$$\therefore \text{slope} = -R_H$$

$$\therefore R_H = -(-10.7 \times 10^{-3} \text{ nm}^{-1}) = 10.7 \times 10^{-3} \text{ nm}^{-1} \\ = 1.07 \times 10^{-2} \text{ nm}^{-1}$$

R_H from the y-intercept: $R_H = 2.8 \times 10^{-3} \text{ nm}^{-1} \times n_f^2$
 $= 2.8 \times 10^{-3} \text{ nm}^{-1} \times 4$
 $= 11.2 \times 10^{-3} \text{ nm}^{-1}$
 $= 1.12 \times 10^{-2} \text{ nm}^{-1}$

Average R_H value from slope and intercept values:

$$1.10 \times 10^{-2} \text{ nm}^{-1}$$

15. Outside of lab, use Excel to create a plot of your data and record here the slope and y-intercept that Excel calculates for the trendline.

What values are on the x-axis? $\frac{1}{n_i^2}$

What values are on the y-axis? $\frac{1}{n} (\times 10^{-3} \text{ nm}^{-1})$

slope from Excel: $-1.121 \times 10^{-2} \text{ nm}^{-1}$

R_H from the slope: $1.121 \times 10^{-2} \text{ nm}^{-1}$

y-intercept from Excel: $2.756 \times 10^{-3} \text{ nm}^{-1}$

R_H from the y-intercept: $1.102 \times 10^{-2} \text{ nm}^{-1}$

Average R_H value from slope and intercept values:

$$1.111 \times 10^{-2} \text{ nm}^{-1}$$

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16. Record and compare the *three* average values you have determined for R_H with the literature value $1.097 \times 10^7 \text{ m}^{-1}$. Show your work for the % error calculations.

Table 1-3. Experimentally-determined R_H values and % Error.

Value of R_H	% Error from literature value
R_H from Q5 $1.09 \times 10^7 \text{ m}^{-1}$	$\% \text{ error} = \frac{ 1.09 \times 10^7 \text{ m}^{-1} - 1.097 \times 10^7 \text{ m}^{-1} }{1.097 \times 10^7 \text{ m}^{-1}} \times 100$ $= 0.638\%$
R_H from Q14 (hand-drawn plot) $1.10 \times 10^7 \text{ m}^{-1}$ $(= 1.10 \times 10^7 \text{ m}^{-1})$	$\% \text{ error} = \frac{ 1.10 \times 10^7 \text{ m}^{-1} - 1.097 \times 10^7 \text{ m}^{-1} }{1.097 \times 10^7 \text{ m}^{-1}} \times 100$ $= 0.273\%$
R_H from Q15 (Excel plot) $1.111 \times 10^7 \text{ m}^{-1}$ $(= 1.111 \times 10^7 \text{ m}^{-1})$	$\% \text{ error} = \frac{ 1.111 \times 10^7 \text{ m}^{-1} - 1.097 \times 10^7 \text{ m}^{-1} }{1.097 \times 10^7 \text{ m}^{-1}} \times 100$ $= 1.276\%$

17. Discuss benefits and drawbacks for the three approaches for determining an accurate value for R_H (i.e., single data point, slope of plot, y-intercept of plot). Which method would you recommend to someone hoping to get the most accurate value? Why?

The first approach is the most straightforward one since it is merely based on observations. However, it is easier to make errors while reading the wavelength using our naked eye. The second and third approaches are mostly based on graphs, data, and calculations. They both use the y-intercept and the slope of the graph to determine the R_H value. I would recommend using the second approach to get the most accurate data, because the result is the closest among all three, and the percentage of error is the smallest based on our calculations we made in question 4.6.

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18. Neatly transfer the data from your notebook to Table 1-4.

Table 1-4. Flame test results and observations.

Sample solution	Color of solution	Color of flame	Metal ion responsible for color of flame
$\text{CuCl}_2 \cdot \text{H}_2\text{O}$	light blue	bright green	copper
BaCl_2	blurry white	light green	barium
LiCl	green yellow	red	lithium
SrCl_2	light yellow	orange red	strontium
KCl	faint yellow	light purple	potassium
KNO_3	light green yellow	light purple	potassium
Unknown A	light blue	light blue green	copper
Unknown B	light blue	light blue green	copper
Unknown C	light green yellow	light blue purple	potassium

19. Compare your results table with two other groups. Did all three groups reach consensus on these observations? If not, which ones were different? Why do you think they might have been different? (Be specific. "Human error" is not an acceptable answer.) Please provide the station numbers for the two groups you talked with to compare your results.

Compare to station #9, all of our observations descriptions are close, only with minor difference due to individual's subjective view. For example, I wrote "light blue" for the color of CuCl_2 solution while they only have "blue". It is inevitable since everyone views colors and their intensity differently.
 Your station #: 2 Comparison station: 9 Comparison station: 11

20. Suggest a better method for determining the identity of these unknown solutions. Why would it be better? Are there any disadvantages to using the method you recommend?

We can identify the unknown solutions using other properties such as its color, conductivity, melting / boiling point. For example, we could compare the unknown substance's boiling point with other known substances. It is easier and more convenient to follow the boiling point pattern along the periodic table. However, it may be dangerous to perform since it involves the use of fire.