Summary of the
Spectra Experiment

This document summarises the *Spectra Experiment*. The full description of the experiment appears at:
http://www.upscale.utoronto.ca/IYearLab/Intros/Spectra/Spectra.html.

Apparatus Notes

- Align the cross hairs in the eyepiece to form an x, not a +.
- Move the eyepiece in and out until the focus of the cross hairs is as sharp as possible.
- Adjust the slits to just resolve the two yellow lines in the Sodium Spectrum.

Calibration

Use the Helium lamp for calibration. Fit your data to the Hartmann dispersion relation:

$$y = \frac{m}{\lambda - \lambda_0} + b$$

λ_0 is a constant for the spectrometer, and is supplied.

Hydrogen Spectrum

Measure the wavelengths of the lines in the Hydrogen spectrum to determine R_H where:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2}\right), n = 3,4,5,...$$

Significance of R_H

Calculate $h\ c\ R_H$, where h is *Planck's constant*, and c is the speed of light. Convert to *electron-volts* and compare to the ionization energy of atomic Hydrogen, which is 13.6 eV.

Use the equation in *Preparatory Question* 4 to discuss the significance of your result.

Gas Identification Sleuthing

Choose at least one of the unknowns and identify it.

Preparatory Questions

1. For the figures of the Scale and the Vernier in the full description of the experiment, what is the reading error? Note that the answer will depend on at least:
    a. Your vision.
    b. The quality of the computer monitor you are using.
    c. The resolution of the figures themselves (90 x 90 pixels).

    For the real apparatus, the reading error will depend on at least your vision and the quality of the engraving of the lines onto the spectrometer.
2. You measure the position of a spectral line, and get a scale reading of 9.26. You decide that the reading error is 0.05. Thus:
    $y = 9.26 \pm 0.05$
    Your calibration of the spectrometer using Equation 1 resulted in the values:
    $b = 4.1275 \pm 0.0032$
    $m = 1491.2 \pm 3.5$ nm
    Your spectrometer has a value $\lambda_0 = 283.2 \pm 0.4$ nm.
    a. What is the value and error of (y - b)? What is the dominant error in this value?
    b. What is the value and error of m/(y - b)? What is the dominant error in this value?
    c. What is the value and error of m/(y - b) + λ_0? What is the dominant error in this value? Note that this is the value of the wavelength.

    Note that all the above numbers are fictitious. However, the principles of error propagation and especially learning to ignore non-dominant errors will be the same for your real data.
3. When you measure the Hydrogen spectrum, you will see only four or possibly five lines. However, the Balmer formula seems to predict an infinite number of lines corresponding to the infinite number of integers greater than or equal to 3. Do you think those lines exist in the spectrum?
    a. If your answer is *Yes* why don't you see them?
    b. If your answer is *No* why don't they exist?
4. A simple variation of the Balmer equation is:
    $$\frac{1}{\lambda} = R_H\left(\frac{1}{1^2} - \frac{1}{n^2}\right), n = 2,4,5,...$$
    Do you think these lines exist in the Hydrogen spectrum?
    a. If your answer is *Yes* why don't you see them?
    b. If your answer is *No* why don't they exist?

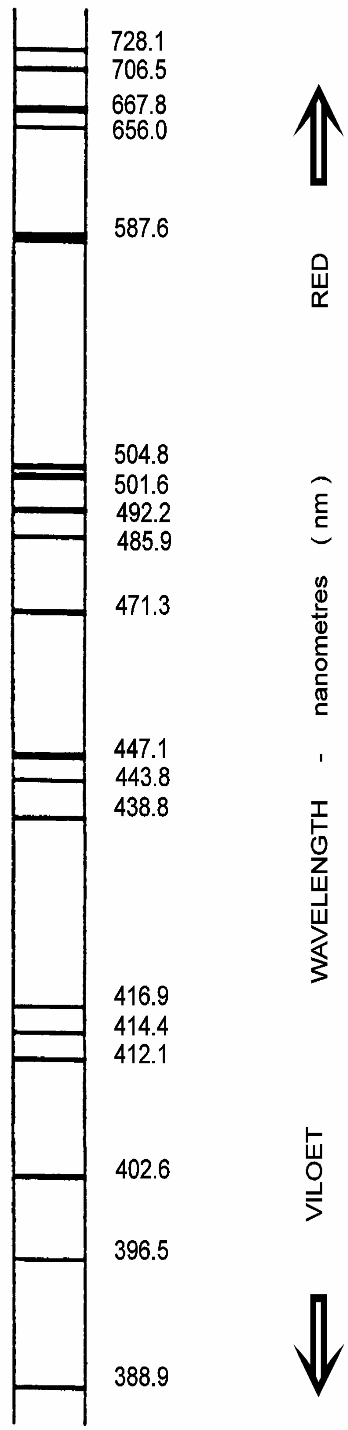
Spectral Wavelength Tables

1. Use the intensity indications with caution. They are only a general guide, and your lines may have different intensities.

2. The tables give most of the lines you will be able to see, and many that you won't be able to see if you are using a narrow slit width. However, they are not complete.
3. Lines separated by less than 1 nm will not be resolved if the slit is wide. If the slit is narrow, weak lines won't be seen.
4. You may assume that errors in the wavelengths are negligible. Typically wavelengths are known to 0.00001 nm or better.
5. A full set of wavelength tables is maintained by the U.S. National Institute for Standards and Technology at http://physics.nist.gov/cgi-bin/AtData/lines_form.

HELIUM

WAVELENGTH nm	*RELATIVE INTENSITY*	*COLOUR*
728.1	2	RED
706.5	4	RED
667.8	6	RED
656.0	1	RED
587.6	10	YELLOW
504.8	4	GREEN
501.6	6	GREEN
492.2	5	GREEN
485.9	2	GREEN
471.3	5	BLUE
447.1	6	BLUE
443.8	1	VIOLET
438.8	4	VIOLET
416.9	1	VIOLET
414.4	2	VIOLET
412.1	3	VIOLET
402.6	4	VIOLET
396.5	1	VIOLET
388.9	3	VIOLET



ARGON

WAVELENGTH nm	*RELATIVE* INTENSITY	COLOUR
574.0	2	GREEN
565.0	3	GREEN
560.7	3	GREEN
557.3	3	GREEN
549.6	3	GREEN
522.1	2	GREEN
518.8	3	GREEN
516.2	3	GREEN
470.2	1	BLUE
462.8	1	BLUE
459.6	1	BLUE
452.2	1	VIOLET
451.1	2	VIOLET
433.5	2	VIOLET
433.4	2	VIOLET
430.0	3	VIOLET
426.6	3	VIOLET
425.9	3	VIOLET
420.1	2	VIOLET
419.8	2	VIOLET
416.4	3	VIOLET
415.9	2	VIOLET
431.9	2	VIOLET

KRYPTON

WAVELENGTH nm	*RELATIVE* INTENSITY	COLOUR
645.6	5	RED
642.1	5	RED
605.6	2	RED
601.2	2	ORANGE
599.4	2	ORANGE
588.0	1	ORANGE
587.1	10	ORANGE
584.1	1	YELLOW
583.3	1	YELLOW
570.8	1	GREEN
567.2	1	GREEN
565.0	1	GREEN
558.0	1	GREEN
557.0	10	GREEN
556.2	2	GREEN
450.2	5	VIOLET
446.4	5	VIOLET
445.4	5	VIOLET
440.0	2	VIOLET
437.6	5	VIOLET
436.3	4	VIOLET
432.0	3	VIOLET
427.4	5	VIOLET

Argon has many faint lines in the red and yellow which vary in intensity depending on the source and because of the confusion that this can lead to only wavelengths less than 580 nm are given. In this region there are a very large number of lines. Only relatively brighter ones are listed. Fainter ones may provide a haze in the background.

MERCURY

WAVELENGTH nm	*RELATIVE INTENSITY*	*COLOUR*
708.2	1	RED
704.5	2	RED
690.7	1	RED
671.6	1	RED
658.5	1	RED
638.3	2	RED
623.4	2	RED
612.3	2	RED
607.3	2	ORANGE
602.4	2	ORANGE
601.7	1	ORANGE
589.0	1	YELLOW
579.1	8	YELLOW
577.0	6	YELLOW
567.7	1	YELLOW
567.6	1	YELLOW
546.1	10	GREEN
536.5	1	GREEN
520.5	1	GREEN
519.6	1	GREEN
512.1	1	GREEN
504.6	1	GREEN
502.6	1	GREEN
496.0	1	GREEN
491.6	5	BLUE
452.3	1	BLUE
435.8	6	VIOLET
434.8	2	VIOLET
433.9	1	VIOLET
421.2	1	VIOLET
420.6	1	VIOLET
415.7	1	VIOLET
407.8	5	VIOLET
414.7	5	VIOLET

XENON

WAVELENGTH nm	*RELATIVE INTENSITY*	*COLOUR*
647.3	2	RED
647.0	3	RED
631.8	5	RED
620.1	1	RED
619.8	1	RED
618.2	3	RED
618.0	1	RED
617.8	2	RED
616.4	1	RED
593.4	2	ORANGE
593.1	1	ORANGE
589.5	2	ORANGE
587.5	1	ORANGE
582.5	2	YELLOW
582.4	3	YELLOW
571.6	1	YELLOW
569.7	1	YELLOW
569.6	1	YELLOW
546.0	1	GREEN
539.3	1	GREEN
502.8	3	GREEN
492.3	4	GREEN
491.7	4	GREEN
484.3	4	GREEN
483.0	4	GREEN
480.7	5	GREEN
479.3	1	BLUE
473.4	5	BLUE
469.7	4	BLUE
467.1	10	BLUE
462.4	5	BLUE
458.3	1	VIOLET
452.5	2	VIOLET
450.1	2	VIOLET

NEON

WAVELENGTH nm	*RELATIVE INTENSITY*	*COLOUR*
724.5	1	RED
717.4	1	RED
703.2	5	RED
702.4	3	RED
692.9	6	RED
667.8	7	RED
659.9	7	RED
653.3	7	RED
650.7	7	RED
609.6	5	ORANGE
607.4	7	ORANGE
603.0	5	ORANGE
596.5	4	ORANGE
588.2	6	YELLOW
585.2	10	YELLOW
540.1	5	GREEN

Many orange and yellow lines have been omitted as well as all lines of wavelength less than 540 nm (hundreds). Most of these are faint but some overlap gives the appearance of bright lines.

NITROGEN

WAVELENGTH nm	*RELATIVE INTENSITY*	*COLOUR*
497.6	3	GREEN
491.7	3	GREEN
481.5	3	GREEN
472.4	3	BLUE
466.7	3	BLUE
464.9	3	BLUE
457.4	3	BLUE
449.0	3	BLUE
441.7	3	VIOLET
435.5	3	VIOLET
434.4	2	VIOLET
427.0	2	VIOLET
420.1	2	VIOLET
414.2	2	VIOLET
409.5	1	VIOLET
406.0	1	VIOLET
399.8	1	VIOLET
394.3	1	VIOLET

Since **nitrogen** is a molecule, the spectrum consists of bands rather than lines. This is due to rotation of the molecules. In the visible the most prominent structure is the First Positive series with about 30 regular spaced bands in the region 500-700 nm. Only the band heads of the Second Positive series are tabled above. The bands trail off to shorter wavelengths. As indicated by the relative intensities on a scale of 10, the Second Positive series is less intense than the First Positive series.