Student Learning Assessment (SLA) Report
MAY 2006

Department of Chemistry
Assessment Coordinators: Dr. Francis Patron and Dr. Nairmen Mina

SECTION I: Mission and Student Learning Outcomes (Graduating Student Profile)

Mission
Our mission is to offer a program of excellence in Chemistry through formal education in chemistry, research and service to the community. To foster their development as professionals in all the different areas of Chemistry. Students who graduate from the program will be aware of the problems affecting the Puerto Rico and international communities. They will also be aware of alternatives and responsibilities they have as human beings and scientists in the different areas of endeavor: education, industry, government, or scientific research and related areas.

Student Learning Outcomes
The student who graduates from the bachelor's degree program will have the following knowledge and skills

1. Knowledge of chemistry
   a. They will have a fundamental knowledge in the traditional areas of chemistry, with a balance among theoretical, empirical and applied knowledge.
   b. They will be able to design and perform experiments
   c. They will be familiar with safety regulations in the chemistry laboratory
   d. They will be able to use techniques and instrumentation needed to practice the chemistry profession in industry, academia and government.

2. Interdisciplinary and team work skills
   a. They will have effective skills for team work.
   b. They will have the capability to work in interdisciplinary projects.

3. Problem Solving
   a. They will have the capability to identify and formulate problems of a chemical nature.
   b. They will be able to use their knowledge in different areas to solve problems of a chemical nature.
   c. They will have the capability to critically evaluate the solution to problems
4. Critical thinking
   a. They will have scientific reasoning skills
   b. They will have the ability to analyze and interpret experimental data
   c. They will have the capability of obtaining and synthesizing scientific information of different sources.
   d. They will be able to evaluate critically the sources of scientific information.

5. Communication: Transmission and acquisition of scientific information
   a. They will have effective oral communication skills in Spanish and English.
   b. They will have effective scientific writing skills in Spanish and English.
   c. They will be familiar with the use of library resources and the scientific literature
   d. They will master the use of computational technology and information systems.

6. Professional development
   a. They will be aware of the importance and necessity of maintaining a continuous learning process through their professional life.
   b. They will have the capability of identifying activities (workshops, short courses, etc) that provide continuous education of excellence.

7. Social and Ethical Responsibility
   a. They will have developed the ethical and cultural values needed to serve in our democratic society. They will be aware of the social and global impact of the practice of their profession
   b. They will know the regulations of the chemistry profession as well as the corresponding professional and ethical responsibilities

8. Esthetical values
   a. Will have developed an appreciation for the arts and humanities.
### SECTION II: Student Learning Assessment Results

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>The purpose of this assessment project was to help students develop their scientific reasoning skills, their ability to analyze and interpret experimental data as well as to enhance their capability to express them in writing.</td>
<td></td>
</tr>
<tr>
<td>The project was directed to a population of second year students who take analytical chemistry laboratory courses (QUIM3025 &amp; QUIM3055).</td>
<td></td>
</tr>
<tr>
<td>About 100 students are enrolled in the analytical chemistry laboratory courses (QUIM3025 &amp; QUIM3055) each year.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Justification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical data obtained from students and alumni surveys indicated that there was a deficiency in the area of laboratory report writing. Specifically in the analysis of results.</td>
<td></td>
</tr>
<tr>
<td>Faculty members have consistently found that students do a poor job in the lab reports and specifically in the analyses of the results and the interpretation of their data. This area requires, in addition to knowledge in chemistry and writing skills, the use of critical thinking elements.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POPULATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>Approximately 100 students are enrolled in analytical chemistry laboratory courses (QUIM3025 &amp; QUIM3055) each year.</td>
</tr>
<tr>
<td>Faculty</td>
<td>The study focused on second year students who were chemistry, chemical engineering, and Biotechnology majors.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-intervention</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Student performance on the chosen skill was determined from written laboratory reports.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intervention</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In order to help students develop their scientific reasoning skills and their ability to analyze and interpret experimental data in written reports, two workshops were offered to the students enrolled in the courses.</td>
<td></td>
</tr>
<tr>
<td>Guidelines for writing a good discussion and analysis of results were presented in the workshops. Also, models of good and bad lab reports were discussed.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post-intervention</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The effectiveness of the intervention was measured by noting 1) students’ adherence to the guidelines in their discussion of results, 2) their ability to express the ideas in the written report, and 3) the presence of critical thinking elements in their discussion, analysis of results and conclusions.</td>
<td></td>
</tr>
</tbody>
</table>
### Results

- After the intervention the laboratory instructors observed an improvement in the quality of the discussion of results in the laboratory reports. The reports showed the presence of critical thinking elements in the discussion and analysis of the results.
- Out of 71 students who participated in the workshops, 35 reached a satisfactory level of performance, 17 students showed moderate improvement, and 19 showed no progress at all. This was determined by comparing the reports to the rubric and to reports from previous semesters.

### Possible Reasons or Hypotheses

- The intervention was helpful. It helped students developed their scientific reasoning skills, their ability to analyze and interpret experimental data, and their ability to write a discussion of results.

### Dissemination of Results

- Oral presentation to the departmental assessment coordinators of the College of Arts and Sciences at UPRM on May 10, 2006
- Written report submitted to the office of the Dean of Arts and Sciences on May 24, 2006
- Presentation at a Chemistry Department faculty meeting on January 19, 2007

### Course of Action

- The workshops have been permanently incorporated into the analytical chemistry laboratory courses (QUIM3025 & QUIM3055). These courses have been modified and structured as follows:
  - Students perform two experiments
  - Students attend the workshop
  - Students turn in their first report
  - Students received individual feedback about their reports and coaching to help them adjust the discussion of results in their reports to meet the guidelines presented in the workshop
  - Students perform the remaining experiments and turn in reports

### Next learning assessment closing the loop project

- The chemistry department is planning to evaluate the student failure rate in the first year general chemistry course (QUIM 3001 or QUIM3041) and its correlation to the level of mathematics courses completed by students.

### Appendix

- A1. Ejemplo de una Buena Discusión de Resultados (QUIM 3055L)
- A2. Ejemplo de una Discusión de Resultados Pobre (QUIM 3055L)
- A3. Formato para Informes en QUIM 3055L
- A4. Estructura del Taller

Adapted from OMCA UPRM Student Learning Assessment Report Form
A1. Ejemplo de una Buena Discusión de Resultados (QUI M 3055L)

IX. Results

A. Tables:

a. Table of Data and Absorptivity Coefficient*
b. Table of Evaluation of Results for the Determination of Caffeine and Sodium Benzoate in Regular Mountain Dew*

*Available in the next pages.

X. Discussion and Conclusion:

A. Discussion of results:

The concentration of the Benzoic Acid and Caffeine samples were determined by using the stock solutions of each component. It was used the principle of dilution to make the calculation of these concentrations which means that we used the following formula to determine the concentrations of the samples of Benzoic Acid 1-5 and samples of Caffeine 1-5 (BA1-BA5 and C1-C5): \[ C = \frac{M_0 - M}{V_0} \] . The concentrations of the samples in (g/L) for BA1-BA5 were as expected because the aliquots that we used were 2,4,6,8, and 10 mL, which implies that the second sample should have double concentration related to the first sample, the third sample should be three times the first one and so on. (See "Table of Data and Absorptivity Coefficient").

The absorbance of each sample was taken in two different wavelengths that correspond to the wavelength at which each component (Benzoic Acid and Caffeine) exhibits its maximum absorbance. We need the wavelength at which they exhibit its maximum absorbance because that way we are sure that any resultant absorbance from our samples fit in the range of our calibration. The spectrophotometer determined that these wavelengths were 229.5 nm (\( \lambda_1 \)) and 272.5 nm (\( \lambda_2 \)).

It was expected that the values of the absorbance of the samples MDew-A and MDew-B were equal because one was a duplicate of the other but this didn’t occur. The values for the average absorbance of MDew-A and MDew-B at 229.5 nm (\( \lambda_1 \)) are: 0.3825 and 0.3931, and for these same samples at \( \lambda_2 \) the values are 0.1260 and 0.1316. This was due to errors during the preparation of the samples. (See “Table of Data and Absorptivity Coefficient”)

With this data we construct a graph of “Average Absorbance vs. Concentration” for each component (Benzoic Acid and Caffeine) at 229.5 nm (\( \lambda_1 \)) and 272.5 nm (\( \lambda_2 \)). After a least-squares analysis was made with the data it was determined that the correlation factor is 0.9996 for both Benzoic Acid and Caffeine graphs at \( \lambda_1 \) and 0.9906 and 0.9908 for Benzoic Acid and Caffeine graphs at \( \lambda_2 \) respectively, showing that there is linearity among the experimental data which implies that the absorbance of the samples is
directly proportional to their concentration; this last fact demonstrates that the graphs follow the Beer’s Law. (Graphs are available in the next pages.)

As we can observe in the “Graph of Average Absorbance vs. Concentration of Benzoic Acid at 272.5 nm” the first, third, and fifth point, that correspond to BA1 (1.998 E-3, 0.0138), BA3 (6.994 E-3, 0.0517), and BA5 (9.906E-3, 0.0778), does not fit in the trendline and this is the reason why this particular graph has the smaller correlation factor of all the graphs of this analysis (0.9906). In the “Graph of Average Absorbance vs. Concentration of Caffeine at 229.5 nm” and in the “Graph of Average Absorbance vs. Concentration of Caffeine at 272.5 nm” is visible that the third point (C3 (1.199E-2, 0.3241) and C3 (1.199E-2, 0.6008) is almost out of the trendline. This phenomenon shows that there was a problem during the preparation of the samples BA1, BA3, BA5, and C3 or that the spectrophotometer didn’t read the samples correctly. In the case of BA3 is more probable that an error during the preparation occurred because in the graph of “Graph of Average Absorbance vs. Concentration of Benzoic Acid at 229.5 nm” there is also visible that the same sample (BA3) is almost out of the trendline.

The slope of the graphs is equivalent to the Absorptivity Coefficient of the Benzoic Acid and the Caffeine at each wavelength respectively. We obtained the following Absorptivity Coefficients for Benzoic Acid and Caffeine at 229.5 nm (A1): 90.259 and 27.016 respectively. For Benzoic Acid and Caffeine the Absorptivity Coefficients at 272.5 nm (A2) are: 7.9513 and 49.609 respectively. (See “Graphs of Average Absorbance vs. Concentration” and “Table of Data and Absorptivity Coefficient”) The Absorptivity Coefficient is the absorbance of the sample divided by the concentration of the sample. That is why this coefficient for Benzoic Acid and Caffeine is big in one wavelength and small in the other because in one wavelength its absorbance is greater than in the other. We have to keep in mind that one of the wavelengths corresponds to the maximum absorbance of Benzoic Acid and the other wavelength corresponds to the maximum absorbance of Caffeine.

We calculate the standard deviation for each sample at each wavelength. (See “Table of Data and Absorptivity Coefficient”) If we compare these results we can observe that the highest deviation at A1 was 0.0135 that corresponds to C3, and we can observe that BA3 occupies the second position with a value of 0.0129. The highest deviation for the samples at A2 was 0.0093 that corresponds to C3 and it’s followed by 0.0068 which corresponds to BA3. This result agrees with the information provided by the graphs and by the correlation factor of the “Graph of Average Absorbance vs. Concentration for Benzoic Acid at 272.5 nm”. These values of standard deviation indicate that the experiment was worked with precision among the sets of samples, although we lost some precision in samples like BA3 and C3.

In order to resolve a system of equations with two unknowns we need to have two equations in which we can relate one in terms of the other so, using the absorptivity coefficient obtained by the graphs and the average absorbance of the samples MDew-A and MDew-B at A1 and A2 we used simultaneous equations to find the concentration of Caffeine in the samples. With this result we used the equation to find the concentration of Benzoic Acid. For the sample of MDew-A (diluted) we have that the concentration of 1.954 (mg/L) for Caffeine and 3.655 (mg/L) for Benzoic Acid. In the other sample (MDew-B (diluted)) the results are 2.053 (mg/L) for Caffeine and 3.241 (mg/L) for Benzoic Acid. Although we have these results, what we are looking for is to know the
concentration of Benzoic Acid and Caffeine in the undiluted Mountain Dew. So, as the dilution factor is 1:100 (because the undiluted Mountain Dew is 100 times more concentrated than our samples) we have the following results for MDew-A (undiluted): 365.5 (mg/L) or 10.81 (mg/oz) of Benzoic Acid and 195.4 (mg/L) or 5.779 (mg/oz) of Caffeine. For the other sample (MDew-B (undiluted)) we obtained 324.1 (mg/L) or 9.584 (mg/oz) of Benzoic Acid and 205.3 (mg/L) or 6.072 (mg/oz) of Caffeine. (See “Table of Evaluation of Results for the Determination of Caffeine and Sodium Benzoate in Regular Mountain Dew”)

Mountain Dew has as ingredient Sodium Benzoate that is a derivative of Benzoic Acid. Knowing the concentration of the Benzoic Acid in our samples we can relate it with the Sodium Benzoate by stoichiometry. We know that this relation is 1:1 moles, so we calculate the moles of Benzoic Acid and make them equal to the moles of Sodium Benzoate and we found the concentration of Sodium Benzoate in the samples of MDew-A (undiluted) and MDew-B (undiluted). The results of Sodium Benzoate were the following: 431.3 (mg/L) or 12.76 (mg/oz) for MDew-A (undiluted) and 441.4 (mg/L) or 13.05 (mg/oz) for MDew-B (undiluted). (See “Table of Evaluation of Results for the Determination of Caffeine and Sodium Benzoate in Regular Mountain Dew”)

For Caffeine we calculate the percent of error because the manufacturer provides the real value for the concentration of Caffeine in Mountain Dew (theoretical value) that is (37mg/8oz) or 4.625 (mg/oz). The results for the percent of error for Caffeine in mg/oz for the samples of MDew-A and MDew-B are 24.95% and 31.29% respectively. These values demonstrate that the sample of MDew-A has more accuracy that the other sample because it is nearer to the real value of the concentration of Caffeine. It was not possible to estimate the accuracy of Sodium Benzoate because we don’t have the theoretical value of Sodium Benzoate in Mountain Dew. (See “Table of Evaluation of Results for the Determination of Caffeine and Sodium Benzoate in Regular Mountain Dew”)

B. Conclusion:

After the accomplishment of this experiment we practiced the technique of preparing analytical solutions, analyzing solutions with the UV-VIS spectrophotometer, making calibration curves and we determined the concentration of the Sodium Benzoate and Caffeine in regular Mountain Dew. We determined that the concentration of Sodium Benzoate in MDew-A (undiluted) and MDew-B (undiluted) is 12.76 (mg/oz) and 13.05 (mg/oz) respectively. The concentration of Caffeine in MDew-A is 5.779 (mg/oz) and in MDew-B is 6.072 (mg/oz). During the execution of the experiment we face some difficulties with the spectrophotometer that could have influenced in the error of the accuracy of our experiment. (If we put a sample in the spectrophotometer two times, one followed immediately by the other, the spectrophotometer gave two different absorbances for the sample. The difference from one to another could be in the second or third decimal place.)

We can improve these results by practicing the technique of making solutions (this is for the improving the precision) and evaluating the execution of the UV-VIS spectrophotometer (this way we can discard the possibility of a misreading of the absorbance of the samples and see what is affecting the accuracy of our experiment). Our
percent of error were 24.95% and 31.29%, results that we consider too high; but comparing results from previous years and from our classmates we find that they are very similar. These values can represent that the manufacturer is not reporting the real value of Caffeine in regular Mountain Dew.

XII. References:

A2. Ejemplo de una Discusión de Resultados Pobre (QUIM 3055L)

Analysis and Conclusions

In this experiment, “Separation of a Mixture by Gas Chromatography”, we worked with a gas chromatograph and used it to find the retention time, resolution, number of theoretical plates, plate height, and optimum flow of hexane, acetone and 1-propanol, at different flow rates, but at the same temperature. Also, we made the same procedure twice with a mixture of these components, but at different temperatures and same flow rate.

To find the retention time we injected samples of 1µL of each sample by separately. When the chromatograph made the separation of the analyte, we had a graph with a peak of the substance analyzed that gave us the retention time and width of the peak. We used these to calculate the number of theoretical plates (N) with the following formula:

\[ N = \left( \frac{W}{w} \right)^2 \]

in the 1-propanol sample. The values obtained are in the tables presented before. With these values we found the height for the 1-propanol peaks at each flow rate using the length of the column with the following formula:

\[ H = \frac{L}{N} \]

Then, using

\[ R_S = \left( \frac{2^a (tr)^b - (tr)w}{wa + wb} \right) \]

we found the resolution of adjacent peaks at two different temperatures: 80° and 100°.

While we were making the graph of height vs flow rate, we observed that it didn’t have the correct form. We analyzed our results and we noticed that the retention time for 1-propanol at 20mL/min was too high, 3.416 min, compared with the values of our classmates. This could happen because maybe we didn’t inject the correct amount of substance or the detector wasn’t working correctly.

We could say that, without including the 20mL/min retention time value, we were able to separate the analyte of each sample in a retention time similar to the other students and can conclude that we reach our objectives.
A3. Formato para Informes en QUI M 3055L

<table>
<thead>
<tr>
<th>FORMAT FOR FULL REPORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REPORTS IN ENGLISH</strong> (100 points each)</td>
</tr>
</tbody>
</table>

I.  **TITLE** (1%)  

II. **DATES** (1%):  
   Date experiment started:  
   Date experiment ended:  
   Date experiment was submitted:  

III. **PURPOSE** (3%): Be brief but accurate.  

IV.  **DATA** (10%): Include all data collected, tabulated if appropriate. Also include all instrument printouts (e.g., spectra, chromatograms) clearly identified with a figure caption. Include conditions for data acquisition and any other relevant information. Tables should be self-explanatory.  

V.  **CALCULATIONS** (20%): Include one or more calculation of each type. For each equation that you use in computing the desired results, show the equation with a typical set of experimental values plugged in. All graphs must be neatly prepared, with properly labeled axes, (correct number of significant digits and units) and a descriptive title.  

VI.  **RESULTS** (20%):  
   A. **TABULATED RESULTS**: Collect all results and present them as tables. Report them with their associated standard deviations (if possible).  
   B. **ERROR ANALYSIS**: You should list the source and magnitude of expected errors and their influence upon your results (propagation of error analysis). Do not go on talking about your own mistakes in this section unless you really know they did affect your results and how.  
   C. **ACCEPTED RESULTS**: Include in this section accepted or literature values if available for all reported quantities, and give the deviations of your experimental values from these quantities.  

VII. **DISCUSSION AND CONCLUSIONS** (25%): In this section you should show whether or not you have given any thought to what you have accomplished (or learned) in the analysis. Include applications, implications, principles illustrated, improvements, and experience gained. It is your chance to show what you have learned. **ANALYZE** what you have done and **draw intelligent conclusions** from your results.  

VIII. **ANSWER TO QUESTIONS IN LABORATORY MANUAL** (10%)  

IX. **REFERENCES** (5%): List all references used. Use ACS Style format. Ask your Instructor!  

OVERALL REPORT PRESENTATION AND NEATNESS (5%)
**A4. Estructura del Taller**

El taller en el que participaron los estudiantes de Química Analítica tenía la siguiente estructura:

I. Introducción
II. Pre-Prueba
III. Discusión de los elementos del pensamiento crítico
IV. Buenos y malos modelos de informes de laboratorio
V. Post Prueba
VI. Discusión Grupal

**Fechas de los talleres:**
- Martes, 25 de octubre de 2005
- Jueves, 27 de octubre de 2005

**Recursos:**
Coordinadores de los laboratorios de Química Analítica
- Dra. Marisol Vera
- Prof. José I. Padovani

**Distribución de los estudiantes que participaron a los talleres:**
- Ingeniería Química: 28
- Biotecnología: 11
- Biología: 2
- Química: 10
- Microbiología: 2