The identification of drugs by infrared and Raman spectroscopy: An APCELL experiment.*

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Modern vibrational molecular spectroscopy is a powerful analytical technique that is taught in all chemistry courses and is widely used in all branches of chemistry, materials science and increasingly in the biosciences. In modern instruments the necessary computer interface provides a facility that greatly enhances the power and range of applications but is often thought of by students as a "black box". In addition to learning the basic vibrational theory and instrumentation it is necessary for students to also learn how to best use the computing power that accompanies these spectroscopic techniques.

This experiment was designed to support the basic theory of vibrational spectroscopy, spectroscopic instrumentation and the application of vibrational spectroscopy to chemical and forensic analysis. The first part of the exercise involves using computer simulation software to animate molecular vibrations and providing a medium that engages most students and encourages active learning. After an hour of exploring molecules ranging from diatomics to small drugs, students are capable of visualizing the molecular vibrational motions and relating these motions to predicted IR and Raman spectra. This process also leads to a better understanding of the basic concepts.

The experimental work is quite simple but, providing the automated instrumental functions are turned off and the students are required to step their way through the collection of spectra, it provides an excellent support for the instrumental background covered through lectures. The computer manipulation is quite straightforward for the computer literate student, but challenging for those that lack confidence in using modern software. The process of transferring data, manipulating baselines and carrying out a database search provides a further opportunity for students to gain confidence in using computer interfaces and accessing databases. The outcomes of the database searching lead students to critically access their experimental spectra because the database search fails if the spectra have not been recorded optimally. At the end of the practical exercise students will also realize that without a good knowledge of the fundamentals and the instrumental methods and good experimental technique database searching is of no use.

The exercise was developed for a 2nd year unit in Instrumental and Forensic Chemistry with the original idea of identifying micro-fibres and paint chips. The drug identification was eventually chosen simply because it requires no special accessories for the infrared. A laboratory equipped with diamond anvil cells or single bounce pressure ATR systems would provide an opportunity to base the exercise around a more appropriate forensic topic and expose students to modern IR methodology.

Educational Template

Section 1 - Summary of the Experiment

1.1 Experiment Title

Infrared and Raman Spectroscopy for the identification of drugs

1.2 Description of the Experiment

Students carry out the exercise at Monash as part of a level 2 subject "Instrumental and Forensic Chemistry" although it is appropriate for any subject that covers the theory and practical use of infrared and Raman spectroscopy. The notes are written in the context of forensic science and this context appeals to most students. In this exercise students firstly reinforce their knowledge of vibrational spectroscopy theory using a computer program, record IR and Raman spectra of a common pharmaceutical drug and then identify the drug using a searchable database.

The aims of the practical are as follows:

Using a computer simulation program **Animol**

i. Investigate the spectra of small molecules and correlate the bands with vibrational modes.

ii. Obtain a prediction of vibrational spectra of aspirin (acetyl salicylate), salicylic acid and paracetamol (4-hydroxyacetanilide) and compare the spectra. *Note. These could be any useful molecules you wish to enter into the Animol program.*

Record the infrared spectrum of a common pharmaceutical drug using a KBr matrix technique.

Search an infrared spectral database to identify the drug.
Record or obtain the Raman spectrum of a common pharmaceutical drug.

Search a Raman database to identify the drug.
Gain experience in data transfer and spectral manipulation.

* The complete documentation for this experiment is freely available on the APCELL web site [www.apcell.org]. It includes the educational template, a set of student notes, demonstrator notes and technical notes to allow ready implementation into a new laboratory.

The use of the computer simulation program allows the students to reinforce their theoretical knowledge whilst visualizing vibrational modes and relating these modes directly to predicted spectra. Students then have control over their rate of learning and depth of learning. The experimental part is straightforward and kept simple because it is often the first time students have used IR and Raman spectroscopy. The nature of the experiment can allow them to learn about the instrumentation, although this can be de-emphasized for students not involved in instrumentation. Although students should satisfactorily identify the drug in question through database searching they will realise through the practical that a depth of knowledge is required to search the database and achieve the correct result.

1.3 Course Context and Students' Required Knowledge and Skills

The experiment is closely linked to the "Instrumental and Forensic Chemistry" subject at Monash although it would be equally at home in any analytical spectroscopy, physical chemistry or analysis course. Even students doing courses in synthetic chemistry would find this a useful exercise.

Students require knowledge of the theory and instrumentation of IR and Raman spectroscopy and the ability to quickly come to terms with an interactive computer program. The sample preparation for the infrared requires a little skill that is picked up by most students quickly. They also require a familiarity with, or a desire to learn how to transfer data between computers and how to find their way around new computer packages.

1.4 Time Required to Complete

Prior to Lab 30 min
In Laboratory 5 hours
After Laboratory 1 hour

1.5 Other Comments

The exercise consists of the 3 components of spectral measurement, computer visualization and database searching. For shorter prac periods the exercise can be reduced by the removal of one of these components. Similarly if a Raman instrument is not available then the Raman experimental part can be omitted.

The major criticism in the workshop was the length of the prac and the wide variety of tasks expected so I should come clean on how we run this now at Monash. It is split into 2x4 hour pracs.

1. Consists of the Animol exercise together with obtaining IR (nujol mull) and Raman spectra of the analgesics used in the Animol exercise. Students then simply identify the analgesics from the spectra and note the spectral differences. (This is used in 2 2nd year subjects (Chemistry of Life and The Instrumental and Forensic Chemistry)
2. Consists of the Practical part and database searching part only and is used in Instrumental and Forensic Chemistry only.

Both of these pracs are completed by the students in <4hours.

Section 2 – Educational Analysis

Learning Outcomes *What will students learn?*	Process *How will students learn it?*	Assessment *How will staff know students have learnt it?* *How will students know they have learnt it?*

Theoretical and Conceptual Knowledge

Clarification of the concept of normal modes of vibration.	By observing in 3D the normal vibrational modes of small molecules. By comparing the vibrational modes of a number of small molecules	The students will answer questions that require this knowledge on a proforma sheet. Demonstrators will observe the progress of students through the interactive program and mark the proformas.
Clarification of the nature of functional group vibrations in larger molecules	By observing in 3D the vibrational modes of larger molecules and how they vary. By correlating the wavenumber positions of predicted and measured vibrational modes with tables.	The students will answer questions that use this knowledge on a proforma sheet.

Insight into the selection rules of vibrational spectroscopy and complementary nature of IR and Raman.	By comparing IR and Raman spectra both predicted and measured	The students will answer questions that require this knowledge on a proforma sheet.
A knowledge of the theory of IR and Raman instrumentation.	By recording spectra themselves and making decisions on how to best record spectra. By manipulation of the various components of the instrumentation	The students will successfully record high quality spectra which will be assessed by the demonstrator. The demonstrator should also question them about how the instrumentation works during the operation of the instruments

Scientific and Practical Skills

How to effectively record IR and Raman spectra.	By recording spectra themselves and making decisions on how to best record spectra. By manipulation of the various components of the instrumentation.	The students will successfully record high quality spectra which will be assessed by the demonstrator. Demonstrators will assess the success or otherwise of the database search.
Learn some techniques of sample preparation for IR and Raman.	By preparing KBr discs via a pellet press and by using a microscope attached to the Raman instrument.	By observing the appearance of the KBr disc and the quality of the spectra recorded.
How to manipulate and pre-process spectral data prior to database searching.	Direct application of baseline removal routine and removal of cosmic ray spikes prior to database searching.	By successful removal of the features and successful search of the database. Demonstrators will observe the procedures undertaken.
An awareness of the limitations of database searching and how a knowledge of instrumentation and fundamental spectroscopy is still an essential component for an analytical scientist.	By observing the failure of database searching with inappropriate spectra and then its success when the spectra have been manipulated or corrected. Success will only be achieved when their knowledge is used.	By successful use of the database searching and the correct conclusions from the experiment. As written in the practical report.

Generic Skills

Students will become familiar with the use of computers in science and gain skills in their use.	By digital data collection, digital manipulation of the data, by using an interactive modelling and simulation program and by manipulating and searching databases.	By observing the students successfully using the technology and completing the exercise.

Students will become more aware that despite the wide use of computers it is still essential to have the correct science background to solve an analytical problem.	Through the practical they will recognize that decisions can only be made with sufficient background theory in spectroscopy and instrumentation and that a final answer to problem is only possible with that background knowledge.	By the correct decision paths being made through the exercise.
They will learn how to progress through an analytical problem using critical judgement and identify a chemical compound using spectroscopy.	They will only get the same result using IR and Raman spectroscopy if the correct decisions are made through the exercise.	By assessing the final outcome
How to communicate results in a written report.	By writing a report to explain how they arrived at their conclusion.	By assessment of the final report.

Section 3 - Student Learning Experience

3.1 Did this experiment help you to understand the theory and concepts of the topic? If so, how, or if not, why not?
Yes, The simulation program was especially useful in achieving this.

3.2 How is this experiment relevant to you in terms of your interests and goals?
It is a good example of a modern way of introducing and using a spectroscopic technique.

3.3 Did you find this experiment interesting? If so, what aspects of this experiment did you find interesting? If not, why not?
Yes, The forensic angle was interesting and we got to use a range of instruments and computer software.

3.4 Can the experiment be completed comfortably in the allocated time? Is there time to reflect on the tasks while performing them?
Generally more time is required to carry through the range of experiments. It may be better to concentrate on just some parts of the experiment in the available time.
NB. This experiment was carried out in 3 hours for the student analysis but without the IR part

3.5 Does this experiment require teamwork and if so, in what way? Was this aspect of the experiment beneficial?
Working through the Animol program and the database searching as a pair was a good way to learn.

3.6 Did you have the opportunity to take responsibility for your own learning, and to be active as learners?
We did although more time was needed to do this properly.

3.7 Does this experiment provide for the possibility of a range of student abilities and interests? If so, how?
It is quite challenging for most students, although aspects of it can be carried out successfully without a good background.

3.8 Did the laboratory notes, demonstrators' guidance and any other resources help you in learning from this experiment? If so, how?
It was a good learning experience all round.

3.9 Are there any other features of this experiment that made it a particularly good or bad learning experience for you?
It was a lot to ask in the time available.

3.10 What improvements could be made to this experiment?
There is too much for a single lab session and it could usefully be made into 2 or more sessions.. More instructions on the software would be useful.

3.11 Other Comments
[no responses]