# [O10] The 'poor Raymond' investigation: a team work exercise to inspire new students

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## SUMMARY

'The death of my brother Raymond has shocked and saddened us. But, although the police are treating the case as death by misadventure, we suspect that foul play was involved'. So opens our exercise known as 'poor Raymond', which is tackled by all of our first year chemistry students mid-way through their first semester. Although the exercise has many worthy educational benefits, one aspect of it is the most important – that the students enjoy, and are inspired by, a realistic problem for which their scientific skills and views are valued.

In brief, they are introduced to a storyline in which there has been a suspicious death; in order to persuade the police to look seriously at the case, they have been asked (in groups of about 6 amateur chemists) to scientifically assess three clues that might indicate foul play. They need to decide how to analyze the samples (e.g. a splash on a lab-coat, some pills in a bottle, a liquid found in the locker of the deceased); although they are given some guidance, they must plan the experiments, divide the tasks among their group, and go into the labs to analyze the evidence. Having obtained their results, they submit a short team report, and also meet up with all the other 'amateur chemists' to discuss the results they've obtained. We hope that the students benefit from the following features of the exercise:

- We thoroughly engage them in a plausible storyline that is based in their own subject
- They discover that they already know enough science to be able to tackle a difficult problem.
- They have to go into the labs and design/conduct experiments.
- They learn that there are no 'right' answers (only balance of proof)
- They start to learn how to work as a team.

Most of all, the 'poor Raymond' exercise fires up their enthusiasm in the all-important first year of their degree course.

## BACKGROUND TO THE EXERCISE

In common with many degrees in science and engineering, our students arrive at the start of year 1 eager to begin tackling *real* problems in their subject. However, there is a strong tendency for us to use year 1 to simply lay the foundations, ensuring that they learn the fundamental theories and safe laboratory skills, whilst less effort is sometimes given to the essential aspect of inspiring and motivating our students (1). Many courses now use PBL (2) and transferable skills exercises

(3,4) to add variety and extend the range of skills that students develop, and our course is no exception (5). However, it is quite difficult to design material that is suitable for the 1st term/semester of year 1, when students arrive with varied training and limited knowledge within their discipline. We wanted to design an exercise to which everyone could contribute, in which their limited knowledge would be sufficient, that would involve some ‘hands-on’ science, and for which their views would be valued. We chose a forensic science scenario, but one in which they took on the role of ‘capable amateur’, trying to amass sufficient evidence to persuade the police to engage ‘the professionals’.

## STRUCTURE OF THE EXERCISE

The exercise is run over a 1 week period as follows:

- Thursday - 1h lecture slot - Introduction to the exercise
- Monday - 3h lab period - Conduct experiments
- Tuesday - 3h lab period - Conduct experiments
- Thursday - 1h lecture slot - Debriefing (discuss results/submit reports)

## WHAT DO THE STUDENTS DO?

**Introduction**: we carried this out as a role play, with the scene being set, and the exercise presented, by ‘the brother of poor Raymond’. The students arrived with no prior information about the exercise, and no hand-outs are given until the scene is set. This tactic helps to really engage the students, who are then divided up into groups of about 6 – in semester 1, one can either reinforce tutorial groups, or help the students to mix by assembling the groups appropriately. The introduction takes about 20 minutes, and then the students are free to plan the experiments as they think best, and/or to agree to meet up later to plan them (see below for the two handouts they receive).

**Experiments**: the experiments are designed to be too hard to be all carried out within the 2 lab sessions unless the tasks are divided up amongst the group; however, they are short enough that most of the analyses can be carried out in the first lab day, so that they can (often as a group) return to some aspect of the experiments that seemed ambiguous, or for which they would like to obtain additional data. They are asked to prepare a one-page team report for the police, and also decide what steps they might take to preserve the integrity of material that might be re-analysed professionally.

**Debriefing**: they must not only submit their report, but also be ready give their results to the whole class – not actually too demanding, but it gives them some practice at sharing results with a bigger group. This feedback session is very important, as the students start to make some judgment of the validity/ reliability of their results. We have run it with around 15 groups, and so can select 5 groups to provide their results on each of the 3 experiments, each time checking with the rest of the students to see how much agreement there is. This is effectively the same as repeating the results as an analytical scientist would, although the variation isn’t analysed statistically. A key aspect of the debriefing is when the students ask ‘what is the right answer?’ Although there effectively is a correct solution, in that the samples were prepared artificially, a critical aspect of the exercise is that *the ‘correct’ answers are the results the students obtain* – to act out the role-playing realistically, there are no ‘right answers’, just a balance of scientific evidence that leads to a proposal – quite a revelation for many first years!

## POOR RAYMOND (HANDOUT 1)

The death of my brother Raymond was a great shock to me, and to all his friends and family. At 20 years old, keen on all racket and team sports, he was found dead at his place of work, MacKenzies Winery, just 3 days ago. Although the inquest has yet to be held, preliminary enquires by the police suggest 'death by misadventure'. He had been taking a mixture of pain-killers and anti-inflammatory tablets (aspirin and ibuprofen tablets found in his pockets) to help him play squash through a shoulder injury, and an adverse reaction with alcohol at a work's celebration apparently led to a fatal reaction. Raymond had already raised concerns with me about the practices of his present employer, for whom he'd worked for a couple of years. Although leaving school at 16 and going straight into a job, Raymond was a bright guy, and the 'Research and Development Assistant' role he took on was little more than a general skivvy. And the firm didn't seem keen or supportive when he wanted to understand about the underlying science, or when he suggested that he might try to obtain a University degree in chemistry after taking A-levels in evening classes.

Yesterday, one of his close colleagues came to see me. Michael Fletcher had worked alongside Raymond, and the two had discussed their concerns about the additives that the company was using to improve the wines they were selling.

To increase the value of the wine, the company was illegally adding flavourings to the vats. Raymond had managed to smuggle some of this liquid into a vial, which Michael had found in Raymond's locker; they suspected that two components were present, which made the wine sweeter and smell more fruity.

In the step to help remove the insolubles from the wine-making process, the company was meant to add innocuous tartaric acid, but Raymond suspected that a more efficient but illegal alternative was being used. Some of this had splashed onto his lab-coat, and Raymond had cut this out, hoping to isolate and identify the additive, thought to be an aromatic acid.

Finally, Michael had retrieved an almost empty unlabelled bottle from the lab bins. It contained a small amount of a white powder. Michael wondered if one of the firm had been worried that Raymond was finding out too much, and had decided to lace his lunch with drugs, hoping he might then fall asleep on the job and so give the firm an excuse to sack him. If true, this had had unexpected and fatal consequences.

The police suspect nothing, so I need to obtain proof of foul play. I'm hoping you can identify the wine additives from the samples collected by Raymond. Also, if the powder in the bottle were to turn out to have the same mixture of analgesics that Raymond had in his bloodstream (path lab results still pending), then this would be an extraordinary coincidence that the police would have to follow up. As trained chemists, you need to:

1. Identify the two components in the liquid additive.

2. Identify the solid on the lab coat.

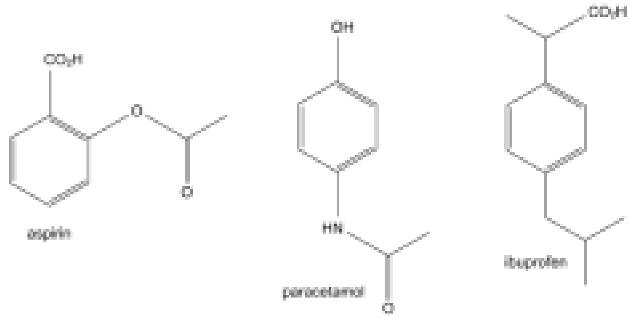
3. a. Gain evidence for the composition of the powder, remembering that ibuprofen and aspirin packets were found on Raymond.
   b. Think about procedures you would carry out to try to ensure that forensic data obtained from the bottle would subsequently stand up in court.

Remember, we're not in a position to carry out a rigorous forensic analysis. What we do want to do is to see if we think Raymond's death was suspicious, and obtain enough evidence to persuade the police to carry out further investigations. In teams of 5–7, you need to plan what you will do, check your method with a colleague (the demonstrators are suitable experts), carry out the analyses next Monday/ Tuesday, and report the results at a meeting on Thursday.

## POOR RAYMOND (HANDOUT 2)

### A few tips and suggestions

1) Pain-killers that are widely used and readily available include:




Good solvents for running TLCs include diethyl ether, dichloromethane, and ethyl acetate (or mixtures of them). The pain-killers should show up on TLC if developed in $KMnO_4$, dil. $H_2SO_4$ (then heating), or in an iodine tank, but the intensity depends both on the substance and the method of development.

2) Some possible carboxylic acid additives are listed below, together with their melting points:

| | | | |
|---|---|---|---|
| (L)-tartaric acid | 170-172°C | p-anisic acid | 183-184°C |
| benzoic acid | 121-122°C | o-chlorobenzoic acid | 138-140°C |
| o-toluic acid | 103-105°C | m-chlorobenzoic acid | 155-157°C |
| m-toluic acid | 108-110°C | p-chlorobenzoic acid | 239-241°C |
| p-toluic acid | 180-182°C | o-acetylbenzoic acid | 116-118°C |
| o-anisic acid | 98-100°C | m-acetylbenzoic acid | 169-171°C |
| m-anisic acid | 106-108°C | p-acetylbenzoic acid | 208-210°C |

(Toluic is the trivial name for methylphenyl, and anisic is the trivial name for methoxyphenyl; o/m/p indicate benzene derivatives which are di-substituted 1,2/1,3/1,4 respectively).

Most aromatic acids will dissolve in standard organic solvents like dichloromethane, diethyl ether, or ethyl acetate. Good solvents to recrystallise them from are mixtures of water and ethanol.

3) Possible additives to the wine are listed below, together with their reported boiling points:

| | | | |
|---|---|---|---|
| methanol | 65°C | propane-1,3-diol | 214°C |
| ethanol | 78°C | methyl acetate | 58°C |
| propan-1-ol | 97°C | ethyl acetate | 77°C |
| butan-1-ol | 116-118°C | ethyl propanoate | 99°C |
| butan-2-ol | 98°C | prop-1-yl acetate | 102°C |
| pentan-1-ol | 136-138°C | but-2-yl acetate | 111-112°C |
| ethane-1,2-diol | 196-198°C | pent-2-yl acetate | 131-132°C |

(What spectroscopic test might help you distinguish alcohols from esters?)

**<u>At the debriefing workshop at 11.00am on Thursday of week 7:</u> you will need to have completed a brief ONE-PAGE report (free-hand is fine, but the one page limit mustn't be exceeded), to hand in to the police. You need to explain what you did, your results, your conclusions, and what each member of your team did for the report. It needs to be clear and succinct, as the police will need to discuss your report with their experts. So that we can collate results at the debriefing on Thursday, you need to bring these results with you, and you will be asked to enter some of them in a grid. You will need to be able to comment on your confidence in the results (or why you are not very confident), and also indicate how your results might be made to stand up in court.**

## 'POOR RAYMOND' INVESTIGATION: NOTES FOR DEMONSTRATORS

The students need to devise their experiments, so they are not following recipes. They need to identify the unknowns, which are:

1. The two liquids are ethanol (b.p. 78 oC) and amyl acetate (pent-2-yl ethanoate) (b.p. 131–132 oC); they will have 20 ml in roughly equal amounts. Good groups should obtain IRs, and look up the peaks expected for esters and alcohols.

2. They each have a piece of cloth, which has about 0.5 g of 2-chlorobenzoic acid soaked into it, and dried. They need to extract with a suitable solvent, recrystallise, and obtain m.p. in order to identify it.

3. The TLC is the trickiest part (see details below). They have a 1:5 mixture (wt:wt) of paracetamol:ibuprofen to identify, and need to compare this with samples of paracetamol, ibuprofen and aspirin. Good groups should be able to get a rough measure of the ratio.

TLC is on Merck Kieselgel 60 $Fg_{254}$ aluminium backed plates. Test solutions are made from powdered tablets. For aspirin and paracetamol 100 mg are shaken with 5 ml of propanone. For ibuprofen 100 mg are shaken with 2 ml of propanone.

A solution of diethyl ether, dichloromethane and tetrahydrofuran in the respective portions of 2:1:05 gives $R_f$ values of 0.62 for ibuprofen, 0.45 for aspirin and 0.22 for paracetamol (THF helps reduce streaking of aspirin). The spots can be visualised using a potassium permanganate solution made up of:

| | |
|---|---|
| Potassium Permanganate | 105 g |
| Potassium Carbonate | 10 g |
| 5% NaOH (aq) | 2.5 ml |
| Water | 150 ml |

Paracetamol produces an instant strong yellow spot; ibuprofen produced a white spot over 2-3 minutes, but aspirin only shows up on heating the plate with a hair-dryer, which bleaches the permanganate and makes the ibuprofen spot difficult to see, so it needs marking with pencil before the plate is heated. Iodine tank and dil. $H_2SO_4$ (aq) also work, but $KMnO_4$ is best.

## ASSESSMENT

The exercise forms part of the transferable skills exercises called 'Communicating Chemistry'. The marking scheme for this is provided at the start of the course, and all exercises receive a letter grade (later converted to a mark). Only those students whose names are on the submitted report receive a grade; similarly, everyone in the group who contributes to the experiments and the report receives the same mark. Other exercises in the communicating chemistry course are carried out individually, in pairs, or in groups.

**More details of TLC of Common Painkillers**

| | Dosage of painkiller per tablet | Wt per tablet | Soluble in $CHCl_3$? | Soluble in $Me_2CO$? |
|---|---|---|---|---|
| Aspirin | 300mg | 0.354g | Yes | Yes |
| Ibuprofen | 200mg | 0.462g | Yes | Yes |
| Paracetamol | 500mg | 0572g | No | Yes |

## CONCLUSIONS

Student feedback on the exercise has been excellent, with this part of their course being singled out for special praise. Perhaps a surprise is the efficiency and quality of the results obtained by the students when they are left largely to their own devices! Across the Faculty of Engineering and Physical Sciences, an important aspect of retaining students has been the introduction of 1st year projects, so that the students can actually start applying their discipline to realistic (if not genuinely real) problems early in their degree programmes.

## ACKNOWLEDGEMENTS

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## REFERENCES

1. C. Anders and R. Berg, 'Factors related to observed attitude change toward learning chemistry among university students', *Chemistry Education Research and Practice*, 2005, **6(1)**, 1-18.
2. S.T. Belt, E.H. Evans, T. McCreedy, T.L. Overton and S. Summerfield, 'A problem based learning approach to analytical and applied chemistry', *University Chemistry Education*, 2002, **6(2)**, 65-72.
3. P.D. Bailey and S.L. Shinton, 'Communicating Chemistry', Royal Society of Chemistry, 1999, pp 141.
4. P.D. Bailey, 'Coaxing chemists to communicate', *University Chemistry Education*, 1997, **1(1)**, 31-36.
5. http://www.umist.ac.uk/departments/chemistry/commchem/index.htm (Note that this site will soon be moving to http://www.manchester.ac.uk – follow links to the *School of Chemistry and Communicating Chemistry* within the undergraduate information).