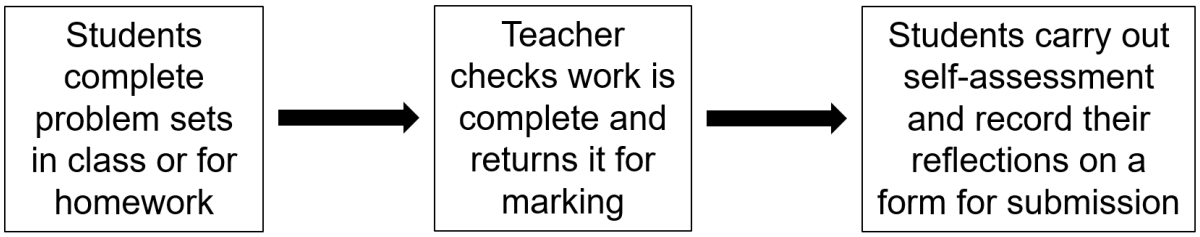
A2 Organic Reaction Mechanisms Booster: Notes for Teachers

Outline

Want a quick overview? Watch this: https://youtu.be/w87W6CBz-eA

The questions in this resource are based on past exam questions, and are designed to be challenging for the students, with the later questions being more difficult and application-based than the earlier ones. The purpose of this resource is for it to be used as a self-assessment exercise, in which the students can mark their own work and reflect on their performance using specially made talking mark schemes. These explain not only the answers to the problems themselves, but also the thought processes that can be adopted in tackling them, as well as the chemistry theory behind it all. This exercise is not about getting everything right, but learning from mistakes, and will hopefully cement the fundamental principles behind mechanistic organic chemistry so that the students are more prepared for their exams and their future studies.

Our suggested plan for running the activity is outlined below:



Week 1: The students should be given the question sheet. They should be advised to complete the work without reference to their notes (you might tell them that you will not be marking it yourself, so they shouldn't worry about getting a low mark). If possible, this could be run as a homework activity, which could be set over a half-term break. In any case, you should ask the students to bring the work to a lesson once they have completed it so you can check that it has been done before they carry out their self-assessment. Once you are satisfied that the work is complete, students can progress to the self-assessment stage, which could also be set as a homework task.

Week 2: Students will complete self-assessment of their work by accessing the talking mark schemes, which are hosted on YouTube. Web links to these videos are included on the record form that students need to complete (either electronically or on paper). Students should complete the form as they go through the marking process. The form allows students to record their marks and also their reflections on their performance. You can then take these forms in to get a sense of what the students have achieved and how they feel about it. The students should be issued a strict deadline (e.g. within a week), by which they should have watched the videos, marked their own work, and reflected on it. A briefing video is available for students, which can be found here: https://youtu.be/l43wYQptRU4

We are likely to update the resources periodically. Check you've got the latest version at: http://www.edshare.soton.ac.uk/18073/

Question 1

This question tackles the electrophilic substitution of a halogen (i.e. Br_2) to benzene to form bromobenzene. We are aware that the halogenation of benzene does not appear on the AQA specification, however we would expect students to be able to apply their knowledge of electrophilic substitution to figure out the answer. To assist with this, the equation for formation of Br^+ has been omitted, and the structure of the electrophile is provided to give the students a straightforward start to the worksheet.

Question 2

Though Question 2 includes a molecule that could be seen as intimidating to the students (acetoacetic acid), the chemistry behind the question is not too tricky. We are again aware that the reduction reaction isn't present on all specifications (i.e. OCR Salters), however the nucleophilic addition reaction mechanism is included on all specifications and as such we would expect the students to be able to tackle the problem by applying what they know about nucleophilic addition reactions.

Question 3

Question 3 is another question regarding electrophilic substitution, but this time for a nitration reaction. The nitration reaction appears on all specifications, and as such the students should be able to tackle this problem well.

Question 4

This is another question regarding nucleophilic addition, but this time with cyanide rather than hydride ions. The general mechanism for this reaction is on all specifications, but the $:CN^-$ nucleophile doesn't appear on the OCR A spec. As such, again we would expect for the students to apply their mechanistic knowledge of nucleophilic addition to account for how this reaction proceeds. For part (c), we have given a definition for 'racemic mixture' as it is not covered in all specifications.

Question 5

This question involves a nucleophilic addition-elimination mechanism, one that is only present on the AQA specification. However, students can use the structures of intermediates to decipher where the curly arrows need to be placed, and using chemical intuition can predict the products of the reaction. This is quite a difficult question, however, and we expect most students to struggle.

Extension Question (6)

The extension question has been designed to really stretch the students. They should be able to apply their mechanistic knowledge to figure out a potential mechanism for how the reaction proceeds, however the presence of a new functional group (the isocyanate) may throw them a bit. This is why we have made this an extension question, due to the high level of conceptual application required.

Final Comments on the Activity

If there is anything in the resource you want clarification on, or are unhappy with, please let us know. We have done our best to include as many reaction mechanisms as possible that are applicable to all exam boards, and as such this does mean crossover of some off-specification material has occurred. We apologise for any inconveniences in that sense. Again, if you have any questions regarding the resource, feel free to email one of us.

Background to the resources: our research project

Having trialled a similar approach during my time as a school teacher, I had been keen to implement a system where students would be able to self-assess their work using an animated mark scheme rather than a static paper-based example. The rationale was to be able to add a verbal commentary to explain and model the thought processes that are used to construct an answer from the perspective of an expert. If delivered correctly, such 'Talking Mark Schemes' should allow students to develop an appreciation of the importance of developing a genuine understanding of the material being studied in preference to instead relying on memorisation and surface learning.

This new approach was first trialled in 2010 in the form of an Easter Exercise issued to develop mechanistic skills in students who had struggled in the January organic chemistry exam. The activity received overwhelming, almost universal, praise from students, and provided data that indicated that there might be an improvement in metacognitive skills for some participants thanks to their engagement with the task. This work led to the award for 'Most Effective Use of Video' from the Association for Learning Technology in 2010, and the findings were reported in 2012.[1]

This was later developed into a programme of self-assessed summer vacation work for students moving from Y1 to Y2 that continues to this day and also proves very popular. It had always been the intention that such resources would be developed for use at A-level (or equivalent) and made available to the community, but a lack of time and resources prevented it from happening. Then, in 2014, a 3rd year BSc student with a strong interest in organic chemistry elected to do a project in the Education section, and the creation of a self-assessment exercise for A-level chemists became the focus of the work. Steve Barnes designed and created two resources, supporting AS and A2 students, and accompanying talking mark schemes for dissemination. Over two years, >1500 students from >25 schools and colleges took part in a trial, and the data collected provided strong evidence that the resources had been very well received by a large majority of participants, and also that their learning had been enhanced by the experience.

This work is the subject of a manuscript currently in preparation for publication in a journal, but some key headlines can be shared here (see overleaf). Remarkably, the key statistics were identical in % terms in both years.

[1] Brown, R. C., Hinks, J. D. and Read, D., *New Dir. Teach. Phys. Sci.*, 8, 2012, pp.33-37.

- *85% of students strongly agreed/agreed that understanding was furthered*
- *73% strongly agreed/agreed that the TMSs were more helpful than published mark schemes*
- *71% said that their confidence in answering questions was increased*

Of course, this relies on the analysis of self-reported responses to survey questions, but that is the tool available to us to probe as best we can, and these are highly encouraging. The point about confidence is particularly pleasing, given that confident students are more likely to approach an assessment with an open mind that allows them to apply their knowledge to solving challenging unseen problems.

This approach also ensures that students reflect on their performance by recording their responses to questions and prompts, thus promoting the kind of reflective approach that is essential for the development of crucial work-place skills and independence. All too often this is lost because of the success students have had previously when adopting a 'cramming' approach to their studies, where everything is focussed on a high-stakes gamble on last minute revision to get over a qualification hurdle. Such endeavours are encouraged in the UK system by the conveyor belt of assessments and examinations that students have experienced from as young as seven, and there appears to be a growing market for revision guides, along with buoyant uptake of intensive revision courses and personal tuition.

Full details will accompany the forthcoming publication, and this will not be discussed further here. If you are interested in learning more, please don't hesitate to contact me directly d.read@soton.ac.uk. You may also be interested to know that some teachers have already developed their own talking mark schemes with interesting findings. Check out Rob Campbell (@NhhsRobert) and Tom Husband (@rhymingchemist), the latter of whom has written a blog about his experience, which can be read here: http://tinyurl.com/zms3ssk

Finally, we are not claiming to be the first to have done this, although it was first done here in 2010 and was based on something first trialled with stating handwritten mark schemes in 2006. We would be delighted to hear from anyone else who has been doing this kind of thing, and would like to share their experiences. Similarly, we'd love to hear from anybody who has decided to have a go at doing it themselves after engaging with our resources. There might be the scope for further collaborative research, and we would very much like to pursue that kind of thing in the future.

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We would like to continue this work, but to do so we need to collect evidence regarding its value. Please let us know when you use the resources, and what you think of them either by email (d.read@soton.ac.uk) or by completing our survey: https://www.isurvey.soton.ac.uk/22353