Module 6 - What Can MR Signal Tell Us About the Spin Environment?
Instructor's Manual

Suggested Prior Modules

Module 4.

Particular prior knowledge from Module 4 that students are expected to have already learned:

- The Bloch sphere representation of spin-½ quantum states.
- Some familiarity with the Bloch simulator.
- The use of pulses to control quantum spins.

If you do not have time to do the entirety of Module 4, the Bloch Sphere Representation, Getting Started with the Bloch Simulator, and Controlling Transitions Between Spin States sections should suffice as preparation for this module and could potentially be done as an interactive pre-reading assignment for Module 5. You may want to have students complete a short assessment to verify they have the necessary prior knowledge listed above.

Suggested Use:

The instructions below are suggestions to help students engage with the material in class and were implementations of the materials that the developers used in their classes. However, all sections and questions in this module can successfully be done asynchronously online to serve as a pre-reading assignment in preparation for class or lab.

This module is too long to fit into a single 1.5-hour class period (though a single 2 or 2.5-hour class period is doable). If splitting this over two class periods, we suggest starting the second session with *Application Experiment: Which sample has the longest T_1?* This then allows plenty of time for students to think through the T1 experimental procedure and perform the experiment (or analyze the provided example experiment).

Expected Learning Outcomes

At the end of this module, students should be able to...

1. *Differentiate T_1 and T_2 relaxation mechanisms for signal decay (Scientific Ability B9)*

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2. *Evaluate and make a judgment about the design and results of an application experiment by direct comparison with their own solution or conceptual understanding ([Scientific Ability I4](#))*

3. *Choose the correct experimental parameters to optimize T_1 contrast for different samples (Scientific Ability A4)*

Background Information

(10 minutes)

Suggested activity: Have students take turns reading aloud the text, along with the information in the margin. You can have students do a think-pair-share of the discussion questions, and this is a good opportunity to have them practice explaining the reasoning behind their answers.

Observation Experiment: T_2 Relaxation

(20 minutes)

Suggested activity: Students can pair up with one person running the simulator and one recording their answers to the guided inquiry questions. (The instructor can clarify that it is fine if students have the same answers for these questions, but also encourage students to write down who they were working with to give proper attribution that it was a shared effort.) *Students should swap roles for the next section.*

Students will only need about 5 minutes to write down their observations and explanations of what appears to cause T_2 decay. Then the class can come together and read aloud the next section providing all the info about T_2 relaxation, and the instructor can clarify anything confusing or answer questions. Then the instructor can give the students time to complete the remaining guided inquiry questions using think-pair-share.

Observation Experiment: T_1 Relaxation

(30 minutes)

Suggested activity: This section is organized the same as the previous section, so you can do the same things but have students swap roles if they are pairing up to use the simulation. Going over the text and Guided Inquiry Questions 11 - 13 takes more time than in the previous section, which is why this section is a bit longer. Question 13 is a

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good optional challenge question for students to think about in preparation for the next section.

Application Experiment: Which sample has the longest T_1?

(45 minutes)

Suggested activity: This is a good small group activity with 3 - 4 students per group to encourage creative solutions and everyone contributing. This is a great activity for students to look critically at a provided experimental procedure and use it to analyze the provided data correctly. If students have access to a benchtop NMR system, they can perform these experiments themselves running a standard FID experiment and changing the repetition time (or the equivalent variable in whatever system is being used). Note: If you perform this experiment, you should use 1 dummy scan, otherwise the first scan will give you an amplitude that is too large (since the spins have had however long they were sitting in the magnet to realign with the magnetic field).

Reflection Questions

(Any Remaining Time)

Suggested activity: In any remaining time you can choose some or all of the questions as a small group or individual reflection activity. Often these are good open questions that provide an opportunity for students to reflect on everything they have learned in this module. These questions can be completed outside of class as homework and used to assess students' comprehension of the material.

In the last 5 minutes of class: Give the students some time in class to assess themselves on the learning objectives using the provided rubric in the student worksheet, and copied on the next page).

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Scientific Ability	Adequate	Needs improvement	Inadequate	Missing
Is able to differentiate T_1 and T_2 relaxation mechanisms for signal decay	A reasonable explanation is made for the different T_1 and T_2 relaxation mechanisms for signal decay.	The explanation for the different T_1 and T_2 relaxation mechanisms for signal decay uses flawed reasoning, is vague, or incomplete.	The explanation for the different T_1 and T_2 relaxation mechanisms for signal decay contradicts the observed patterns.	No attempt is made to explain the different T_1 and T_2 relaxation mechanisms for signal decay.
Is able to evaluate and make a judgment about the design and results of an application experiment by direct comparison with their own solution or conceptual understanding	An evaluation and judgment of the design and results of the application experiment is given with logical and correct justifications compared with their own solution or conceptual understanding.	An evaluation of the experimental design and judgment of the results of the application experiment is made, but the justification provided may be flawed or incomplete.	An evaluation of the experimental design and judgment of the results of the application experiment is made, but no justification is provided.	No meaningful attempt is made to evaluate or make a judgment about the design or results of the application experiment.
Is able to choose the correct experimental parameters to optimize T_1 contrast for different samples	All experimental parameters to optimize T_1 contrast for different samples are correctly identified.	Most of the experimental parameters to optimize T_1 contrast for different samples are correctly identified.	An attempt is made, but most of the experimental parameters to optimize T_1 contrast for different samples are incorrectly identified.	No attempt is made to identify the experimental parameters to optimize T_1 contrast for different samples.

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