Spin-Lattice and Spin-Spin Relaxation Time Measurements for Mineral Oil and Aqueous $CuSO_4 \cdot H_2O$

Denzel Ayala,* Jonathan DeMaria,† and Serdar K. Gozpinar
State University of New York at Buffalo
Department of Physics
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The resistivity of two cuprates $Bi_2Sr_2Ca_2Cu_3O_{10}$ (BSCCO) and $YBa_2Cu_3O_7$ (YBCO) was measured between 80–160 K to identify their critical temperature as superconductors with and without the presence of a static 122 mT magnetic field. The samples were measured using the Van Der Pauw method. Both materials displayed a high temperature superconductivity with BSCCO showing a $T_c = 105 \pm 7K$ when $B = 0mT$ and $T_c = 98 \pm 14K$ when $B = 122mT$. YBCO had a lower temperature range at $T_c = 91 \pm 2K$ when $B = 0mT$ and $T_c = 88.5 \pm 4K$ when $B = 122mT$.

INTRODUCTION to NMR

This is jhust rankdom test asdfl;kjfdsa ppijls. [1]

Broad intro with applications

basics of physics i.e. nucelar spin and magnetic field alignment

Pulse Sequences

T1 sequence

spin echo

CP method

MG method

EXPERIMENTAL

Equipment

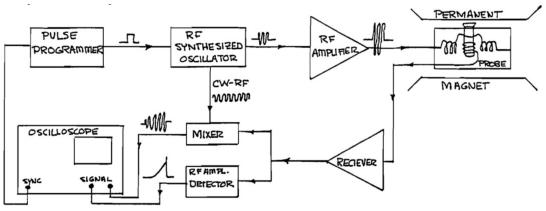

FIG. 1: Block diagram of experimental set up.

A TeachSpin PS1-A system was used to produce/amplify the pulse sequences, and pickup/amplify the output signal. The signal was then processed/synced and displayed on a Tektronix TBS 1052B Digital Oscilloscope. A simplified block diagram of the system is shown in figure 1. The pulse sequence begins at the **pulse programer**. The exact number of pulses, their widths, and time characteristics are defined in this module. This sends two signals, the first goes to the **oscilloscope**, the second to the **RF synthesized oscillator**. This first signal is to let the oscilloscope know when a output signal is coming. The second signal tells the RF synthesized oscillator what pulse sequence to generate. From there the pulse sequence is sent to an **RF amplifier** and the **mixer**. The amplifier ensure that a strong enough signal sequence is transmitted to the transmitter Helmholtz coils in the sample chamber such that it influences the nuclear spins. The mixer combines the reference signal with the sample output signal. Before getting to the mixer the sample output signal goes to the **receiver**. The receiver also sends the output signal to a **RF amplifier detector**. The mixer and RF amplifier detector both send the signal to the oscilloscope.

The **pulse programer**

P1: block diagram and overview of set usepackage

P2: 3module system

p3: sample holder

p4: oscilloscope

Discribe 3 module system, oscilloscope.

Procedure

Sample Preparation

The two chemical species of interest were mineral oil, and $CuSO_4 \cdot H_2O$. The mineral oil was used as purchased from supplier. As $CuSO_4$ is a blue crystalline solid it was dissolved in deionized water prior to measurement.Seven sample concentrations of 0.005M, 0.01M, 0.05M, 0.1M, 0.2M 0.5M, & 1M $CuSO_4 \cdot H_2O$ were prepared.

Chemical species were loaded into their own glass sample vials. Samples should be approximately cubical (5mm tall) so that the magnetic field is experienced uniformly in the entire sample. Sample vials are caped with a rubber stop to ensure that concentrations are consis-

* Denzelay@buffalo.edu; Also at University of Vermont
† jmdemari@buffalo.edu

tent and there is minimal evaporation or contamination. A rubber o-ring was used to adjust the sample depth inside of the probe. The o-ring was placed at the same height for all sample.

Single pulse FID

talk about capaciter, gain, i.e. the stuff that must be done for ALL pulse sequences

Magnetic Field Contours

In order to maximize signal amplitude the spatial dependence of the magnetic field was mapped so the sample can be placed in the section with the most uniform field. This was done by finding the resonant frequency at every point in a regular grid. Field uniformity is determined by a region with minimal change in the resonant frequency. As the resonant frequency of the magnet drift over time due to thermal effects it is crucial to take these measurements rapidly.

The direction of the permanent magnetic field (B_0) will be called the z-axis. The sample holder allowed for freedom of movement in the x and y directions. Here the y-axis moved the sample up and down while the x-direction moved the sample perpendicular to the sample table. The values of the y-axis range from $0 \ldots 20$ cm and begin at the bottom of the magnet and finish at the top. The x-axis places its zero point at the center of the magnet and ranges from $-10 \ldots 10$ cm The field was mapped from -1 $cm \leq x \leq +1$ cm with step sizes of 0.2 cm and from 9 $cm \leq y \leq 11$ cm with step sizes of 0.5 cm.

Spin-Lattice Relaxation: T1 Sequence

A quick estimate of T_1 was acquired. First the spectrometer was set to resonance for a single pulse FID with a large repetition time. The repetition time was slowly lowered until the maximum amplitude of the FID decreased. The point just before the amplitude decrease is $\sim 4 - 5 \times T_1$.

For accurate measurement of T_1 a two pulse sequence of: $180° - \tau(\text{variable}) - 90°$ (FID)

Spin Echo

Carr-Purcell method

Meiboom-Gill method

RESULTS and DISCUSSION

Mineral Oil		
Method	$T_1 \pm$ error (ms)	$T_2 \pm$ error (ms)
Single Pulse	47 ± 4	-
Spin Echo	-	28 ± 1
Carl-Purcell	-	80 ± 20
Meiboom-Gill	-	61 ± 6
$CuSO_4 \cdot H_2O$		
Molarity (mol/L)	$T_1 \pm$ error (ms)	$T_2 \pm$ error (ms)
0.005 M	240 ± 40	130 ± 10
0.01 M	140 ± 30	100 ± 10
0.05 M	17.4 ± 0.7	19.0 ± 0.5
0.1 M	8.2 ± 0.6	8.0 ± 0.4
0.2 M	4.1 ± 0.3	4.9 ± 0.4
0.5 M	1.7 ± 0.1	2.5 ± 0.5
1.0 M	0.75 ± 0.05	1.01 ± 0.04

Single pulse FID

Magnetic Field Contours

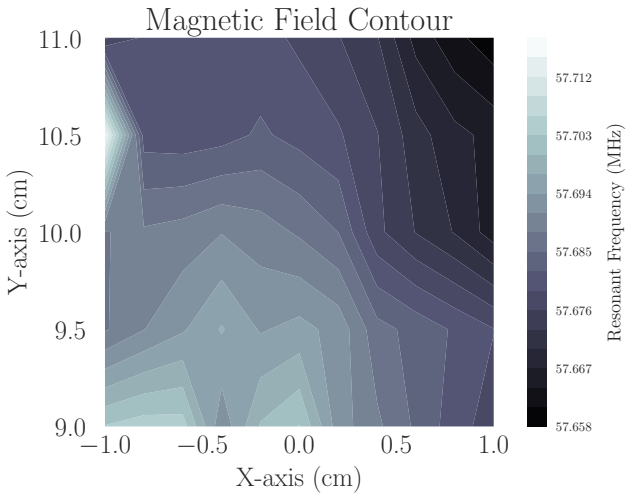

FIG. 2: Contour plot of magnetic field produced by the permanent magnet

Spin Echo

Carr-Purcell method

Meiboom-Gill method

SUMMARY and CONCLUSION

APPENDIX

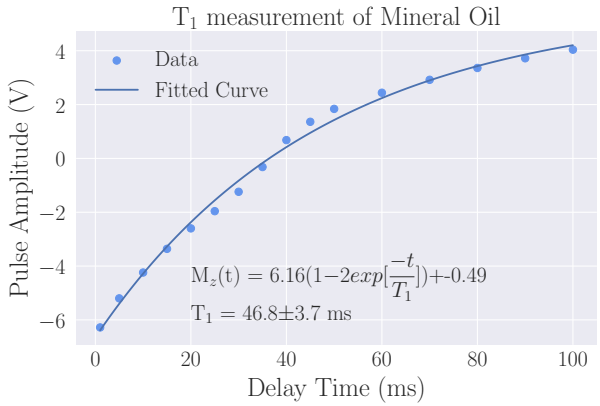

FIG. 3: T1 measurement of mineral oil using the two-pulse method

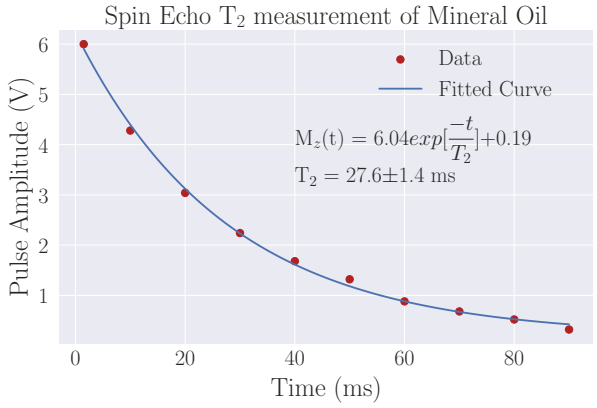

FIG. 4: T2 measurement of mineral oil using the spin-echo pulse sequence

[1] N. W. Ashcroft and N. D. Mermin, *Solid State Physics* (Holt-Saunders, 1976).

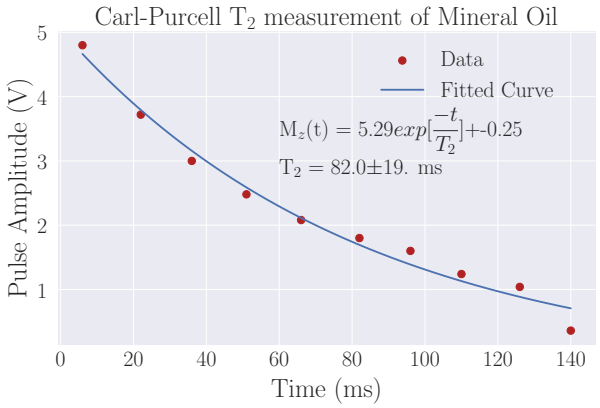

FIG. 5: T2 measurement of using the Carl-Purcell pulse sequence

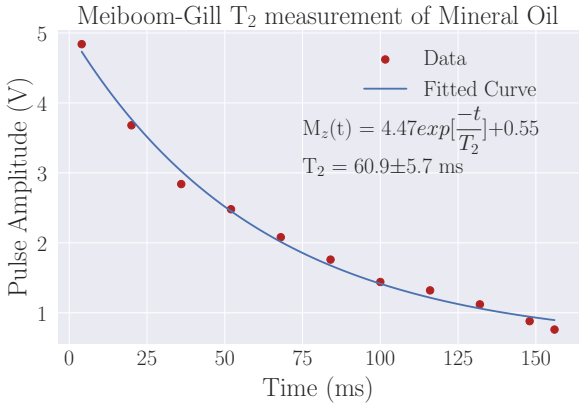

FIG. 6: T2 measurement of Mineral oil using the Meiboom-Gill pulse sequence

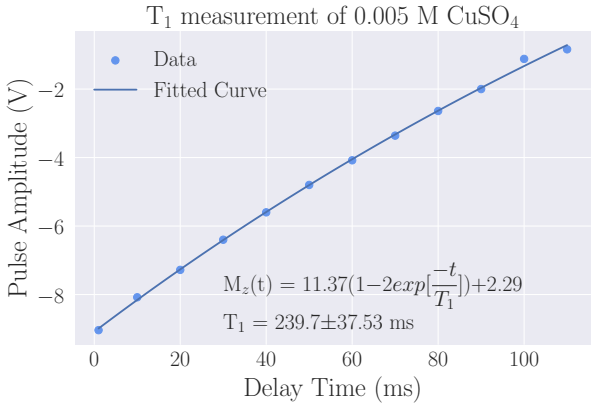

FIG. 7: T1 measurement of 0.005 M $CuSO_4 \cdot H_2O$ using the two-pulse method

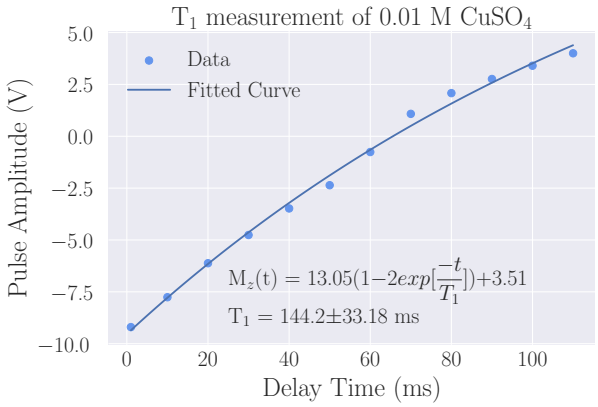

FIG. 8: T1 measurement of 0.01 M $CuSO_4 \cdot H_2O$ using the two-pulse method

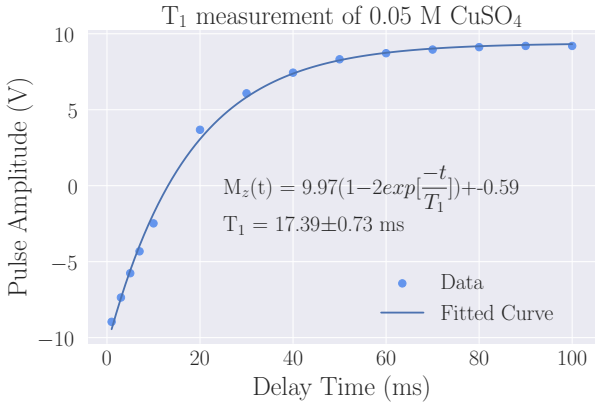

FIG. 9: T1 measurement of 0.05 M $CuSO_4 \cdot H_2O$ using the two-pulse method

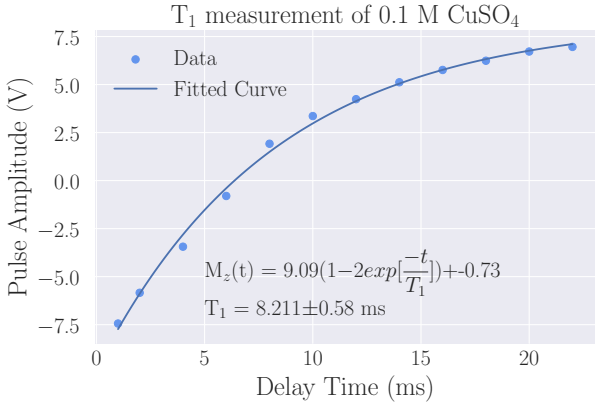

FIG. 10: T1 measurement of 0.1 M $CuSO_4 \cdot H_2O$ using the two-pulse method

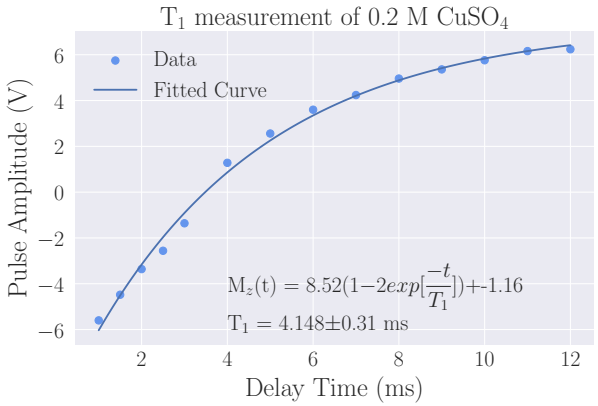

FIG. 11: T1 measurement of 0.2 M $CuSO_4 \cdot H_2O$ using the two-pulse method

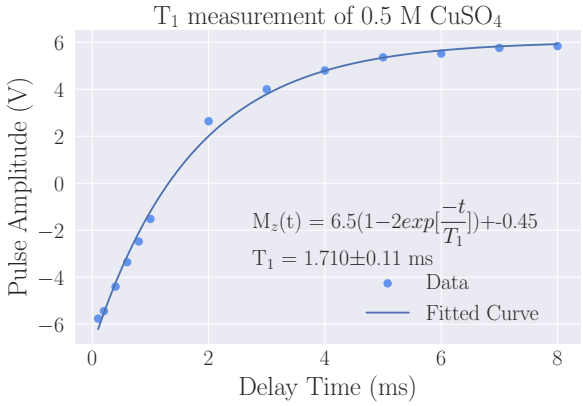

FIG. 12: T1 measurement of 0.5 M $CuSO_4 \cdot H_2O$ using thetwo-pulse method

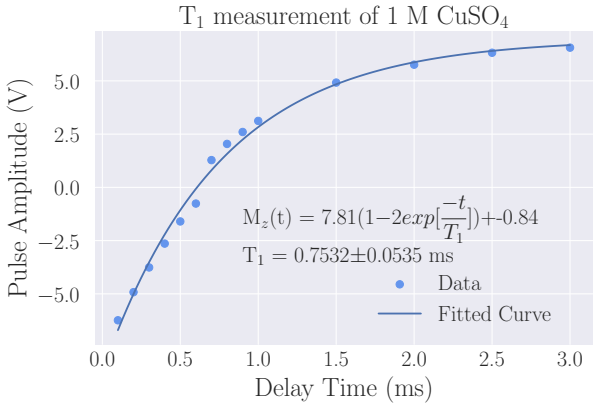

FIG. 13: T1 measurement of 1.0 M $CuSO_4 \cdot H_2O$ using the two-pulse method

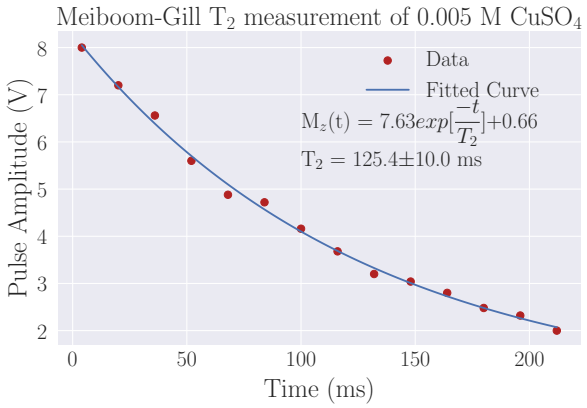

FIG. 14: T2 measurement of 0.005 M $CuSO_4 \cdot H_2O$ using the Meiboom-Gill pulse sequence

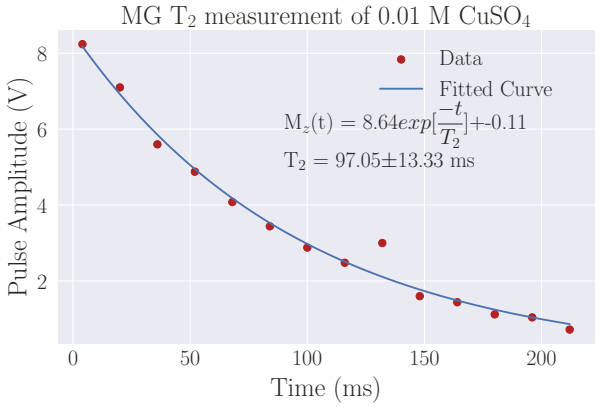

FIG. 15: T2 measurement of 0.01 M $CuSO_4 \cdot H_2O$ using the Meiboom-Gill pulse sequence

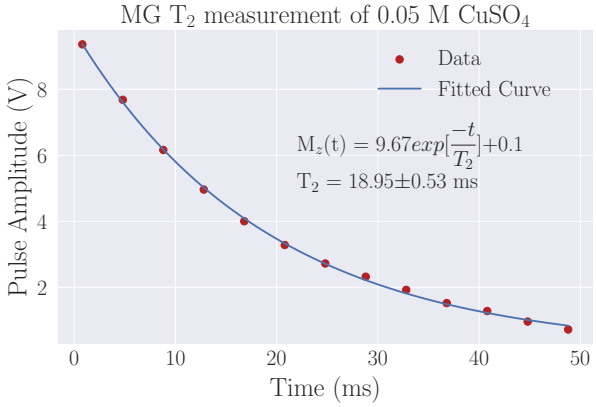

FIG. 16: T2 measurement of 0.05 M $CuSO_4 \cdot H_2O$ using the Meiboom-Gill pulse sequence

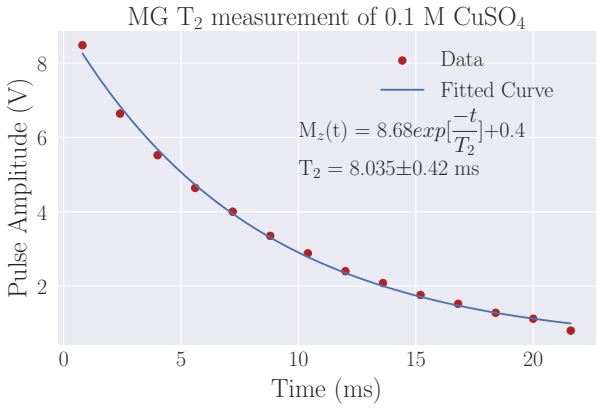

FIG. 17: T2 measurement of 0.1 M $CuSO_4 \cdot H_2O$ using the Meiboom-Gill pulse sequence

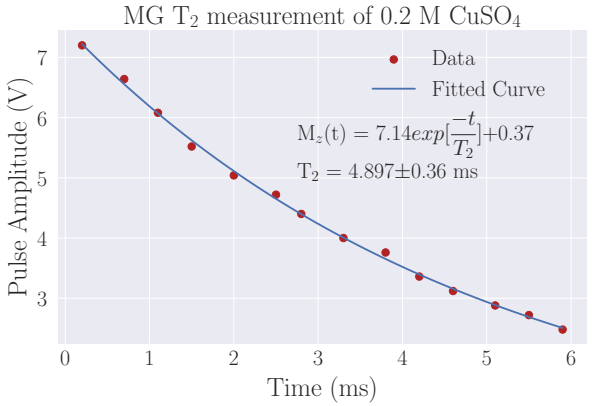

FIG. 18: T2 measurement of 0.2 M $CuSO_4 \cdot H_2O$ using the Meiboom-Gill pulse sequence

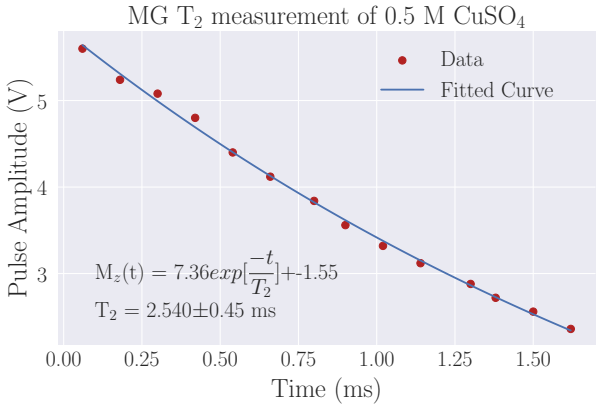

FIG. 19: T2 measurement of 0.5 M $CuSO_4 \cdot H_2O$ using the Meiboom-Gill pulse sequence

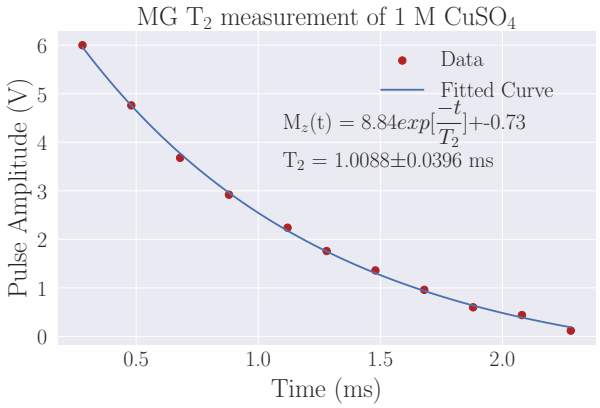

FIG. 20: T2 measurement of 1.0 M $CuSO_4 \cdot H_2O$ using the Meiboom-Gill pulse sequence

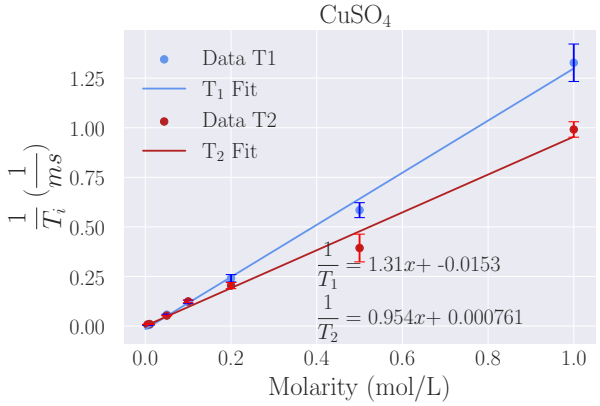

FIG. 21: Inverse Time constants of $CuSO_4 \cdot H_2O$ vs Molarity. Here $1/T_i$ are proportional to $\gamma_p^2 \mu_{eff}^2 N_{ion} \eta / NkT$. Where N_{ion} is the number density and is related to Molarity by $N_{ion} = N_A M$