MLF Experimental Report	提出日 Date of Report: June 17, 2011
課題番号 Project No. 2010A0056 実験課題名 Title of experiment: Mu kinetics in methanol 実験責任者名 Name of principal investigator Khashayar Ghandi 所属 Affiliation Professor at Mount Allison University	装置責任者 Name of responsible person Khashayar Ghandi 装置名 Name of Instrument/（BL No.） MUSE 実施日 Date of Experiment Nov 21/ 2010 Nov 23 /2010

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

All samples were CH3OH (methanol), or solutions of acetone in methanol

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

Our research goals were: 1) to start muonium chemistry in J-PARC by detecting long-lived muonium signals, 2) to test the feasibility of the kinetics experiments with the target cells under a wide temperature range using a cryostat, 3) to measure the kinetics of reaction of Muonium and acetone in methanol.

Muonium (Mu=μ+e−), with a mass only ~ 1/9'th that of its protonic cousin, is quite simply the light isotope of the H-atom. Hydrogen is the simplest atom in nature and consequently the study of its interactions and chemical reaction rates has been central to the field of reaction dynamics. Indeed H atom and Mu are quarks of chemists since studying their reactions provide chemists with the most fundamental aspects of chemistry and chemical dynamics. Therefore, to initiate muonium chemistry in J-PARC after our initial work on muonium formation in methanol at J-PARC (it is just submitted) we decided to investigate the possibility of studying Mu kinetics in non-aqueous systems over a wide range of temperatures, in particular in methanol. In our work on Mu formation in methanol, we have observed Mu over a wide range of temperature from room temperature up to melting point of methanol.

In the work of 2010A0056 for the first time we measured Mu kinetics in methanol over a wide range of temperature.
A typical histogram is presented in Figure 1.

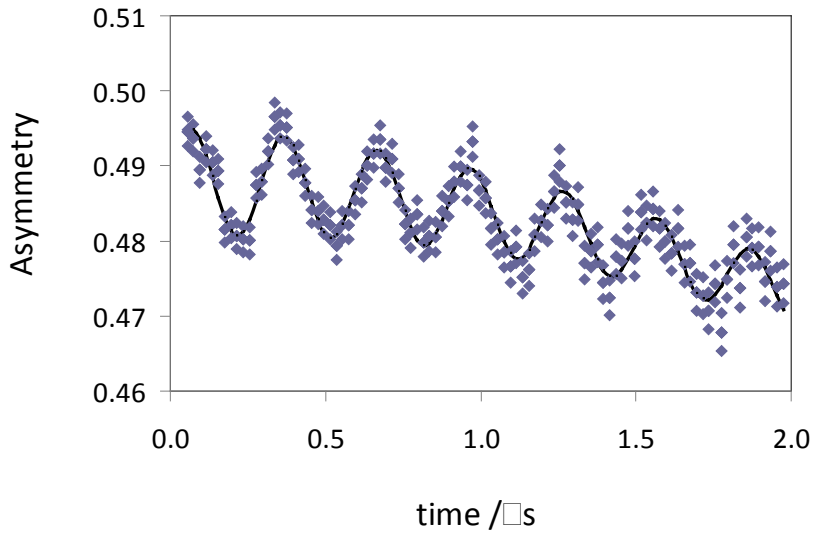

Figure 1 Mu signal in methanol at 180 K (no acetone is added to this sample). The relaxation rates from such data in pure methanol were used as background relaxation rates.

The asymmetry parameter, A(t), in a transverse field experiment includes contributions from paramagnetic Mu, as well as free radical and diamagnetic molecules:

$$A(t) = \Sigma_i A_i \exp(-\lambda_i t)\cos(w_i t + \phi_i) \quad (1)$$

where t is time, A_i is the asymmetry of the fraction *i* in its given environment, λ_i is the relaxation rate of the muon spin in that environment, ω_i is the corresponding precession frequency, and φ_i is the initial phase of this fraction. The parameters of interest in this work — λ_i —were extracted from fits of eqn (1) to experimental data, and provide the kinetics information. In low fields, the two muonium ‘‘triplet’’ frequencies are very close and unresolved, so we fit the asymmetry with a single oscillating term for Mu and a single oscillating term for the diamagnetic species.

In the homogeneous kinetics regime of interest in this work the time dependence of the muon polarization in the Mu atom can be represented by the simple first-order decay expression:

$$[\mathrm{Mu}]_t = [\mathrm{Mu}]_0 e^{-\lambda_{\mathrm{Mu}} t} \quad (2)$$

where $\lambda_{\mathrm{Mu}} = k_{\mathrm{Mu}}[\mathrm{X}]$ is a pseudo first-order rate constant and k_{Mu} is the total rate constant for the reaction Mu + X with reactant “X”. In our case X is acetone.

It should be noted that the total thermalization time of the muon is less than 1 ns, much smaller than typical reaction times, which are set by reactant concentrations to be on the order of 1 μs; therefore the Mu decay rate λ_{Mu} is a measure of thermal reaction rates. In addition to chemical reaction the measured decay rate includes a component λ_b due to "background" relaxation, e.g. spin dephasing due to magnetic field inhomogeneity. The total relaxation rate is expressed as

$$\lambda_{Mu} = \lambda_{Ch} + \lambda_b \quad (3)$$

where $\lambda_{Ch} = k_{Mu}[X]$ is due to chemical reaction of Mu with species X (acetone in our case).

The rate constants measured in this way, are presented in Figure 2 as an Arrhenius plot.

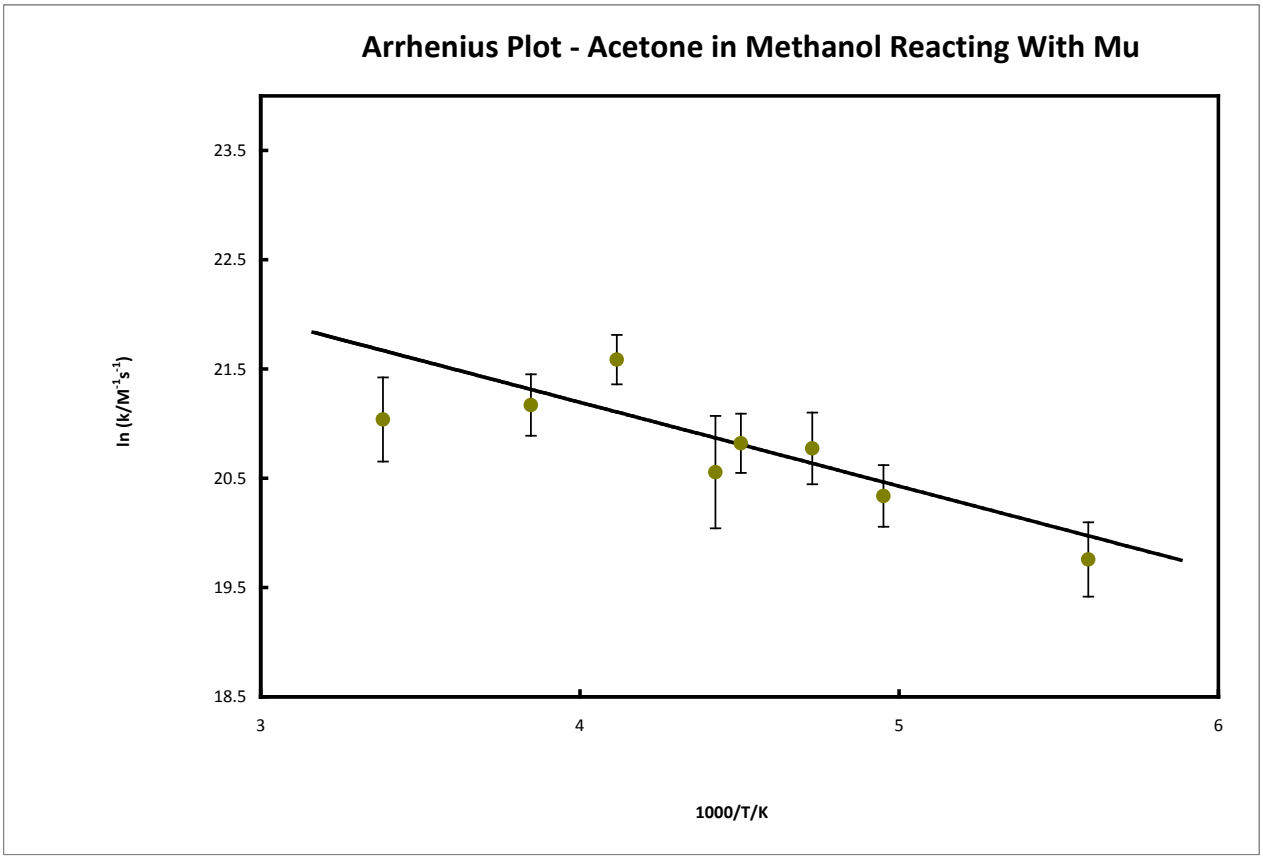

Figure 2 Arrhenius plot of the rate constants for reaction of Mu with acetone in methanol.