First cooling test of rf ion guide gas cell at the SLOWRI facility

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Molecularization is a serious problem in gas catcher cells around the world. It is not so significant for nuclear mass measurements but crucial for laser spectroscopy. If a gas, typically a noble gas, contains a non-negligible amount of impurities such as water, hydrocarbons, nitrogen, and alcohol, thermalized ions have a fair chance to form molecules with impurities. Even though molecules can be broken up *via* collisions with residual gases by acceleration into the high-density region immediately after the gas-cell exit hole, molecular ions have a lower transportation efficiency on an rf carpet. This is because the repelling force produced by rf fields is proportional to the square of ions' mobilities[1] which are generally much smaller for molecular ions than for atomic ions. Gas purification is, therefore, important to avoid the molecularization of injected ions.

We use the highest grade G1 He gas additionally purified through a getter-based gas purifier which provides 99.9999999% purity. Moreover it is desirable that the gas cell is pre-cooled to freeze out impurities onto the inner wall before catching RI beams. In order to cool down the rf ion guide gas cell at the SLOWRI facility, the chamber has a vacuum double-wall structure for vacuum thermal insulation. We prepared two 77-K cryocoolers (Sumitomo CH-110), "cryoU" and "cryoD," as shown in Fig. 1. The gas cell will be cooled by the cryocoolers through aluminum supporters and by a copper pipe winding around the gas cell to carry liquid nitrogen (LN_2). An indium sheet is placed between the supporters and the gas cell for heat conduction. Since the heat capacity of the gas cell is estimated to be as large as ∼300 kJ/K, we conducted a cooling test although only one cryocooler, "cryoD," was ready to use in Sep. 2016. For temperature measurements with the four-terminal resistance measuring method, thermo sensors of type PT100 have been attached at two positions: the gas-cell vessel and the Al support (see Fig. 1).

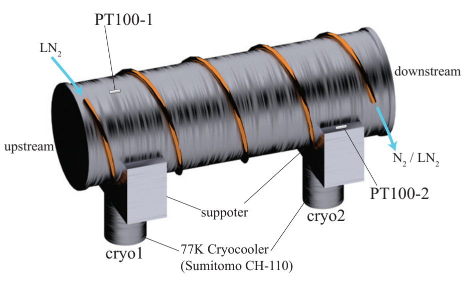

Fig. 1. Schematic of the gas cell cooling scheme.

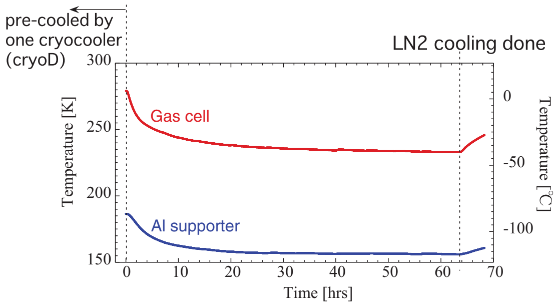

Fig. 2. Preliminary cooling test result.

Figure 2 shows the result of the preliminary cooling test. The gas cell was pre-cooled by cryoD and then started to be cooled with LN_2 at time = 0 in the plot. We continuously kept supplying LN_2 while alternately using the two LN_2 tanks of 120 L and 100 L capacity. It was cooled down to 237 K in one day after the start of LN_2 cooling and to 233 K in 2.5 days. After stopping the cooling, the heating rate was 0.071 K/min. We estimated the conductive heat transfer from this value combined with the estimation of the radiation heat transfer. When object 1 with an outer surface area of A_1 is surrounded by object 2 with an inner surface area of A_2, the radiation heat transfer Q from 2 to 1 is expressed by $Q = \sigma A_1(T_2^4 - T_1^4)/(1/\varepsilon_1 + (A_1/A_2)(1/\varepsilon_2 - 1))$, where σ is the Stephan-Boltzmann constant, ε_i the emissivity of object i, and T_i the temperature of object i. Assuming $\varepsilon_1 = \varepsilon_2 = 0.1$ (typical value for stainless steel), $T_1 = 290$ K, $T_2 = 240$ K, $A_1 = 1.73$ m^2, and $A_2 = 6.72$ m^2, Q was calculated as 0.12 kW, which resulted in a heating rate of 0.024 K/min.. Therefore the heating rate of the conductive heat transfer was estimated to be 0.047 K/min, corresponding to a heat transfer of 0.24 kW, which is thought to be mainly responsible for the heat connection to the unused cryocooler.

Now both cryocoolers are ready to use. We continue the cooling test using both cryocoolers and will introduce many superinsulator layers between the gas cell and the outer vessel to suppress the radiation heat transfer.

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Reference

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