Sodium Iodide (NaI) Purification for Searching on Dark Matter for The COSINE

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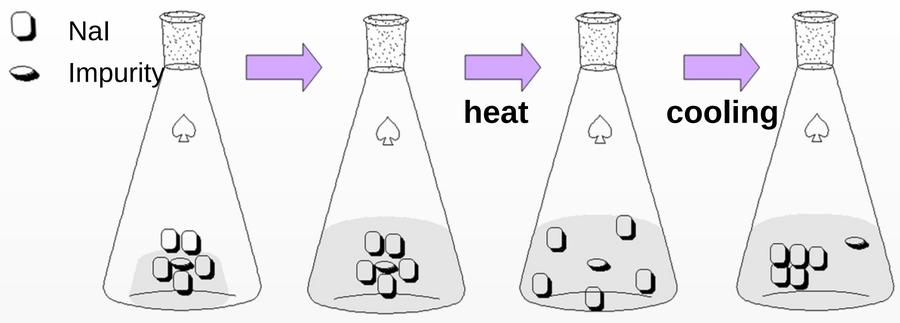
Introduction

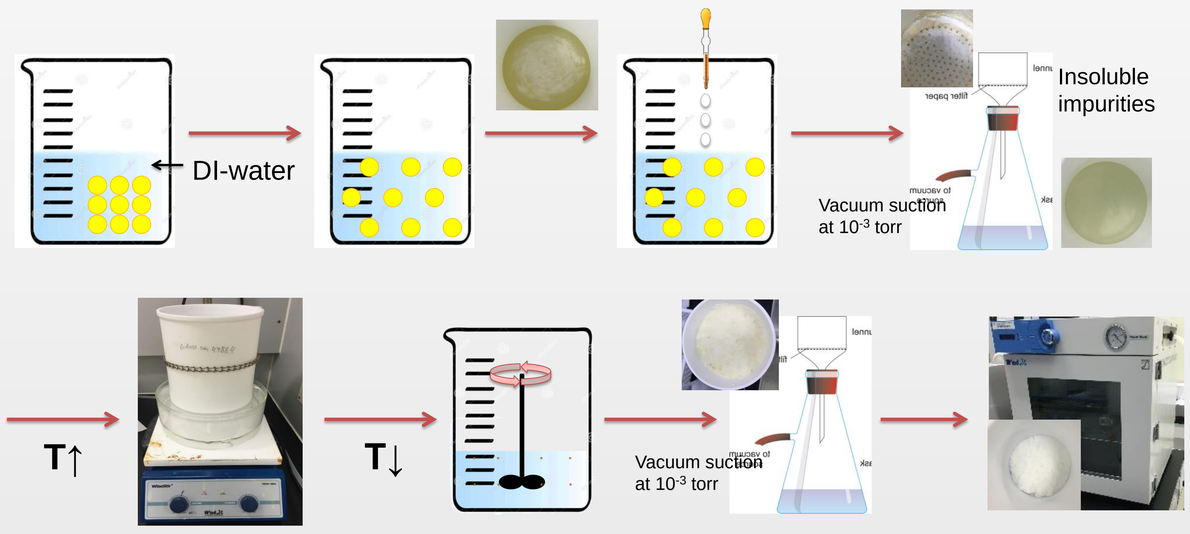
- The COSINE collaboration is developing ultralow-background NaI crystals for searching for dark matter.
- The sensitivity of the experiment is limited by the radioactive background inside the crystal.
- Purification of raw powder is essential to grow the ultralow-background NaI crystal.
- Recrystallization method is one of the effective purification technique based on various solubility at different temperature. Fractional recrystallization was used to remove the natural radioactive isotope impurities from NaI powder.

Experimental

Recrystallization



- NaI solubility in water (g/100ml of solvent)
  - 159.7 (0°C), 179.3 (20°C), 205 (40°C), 257 (60°C), 296 (80°C)



- Sodium Iodide powder (Xi'an, 99.5% purity, technician grade, TG) was dissolved in Di-water
- Introduction of pre-process: reduction agent was used in order to prevent I_2 and IO_3^-
- Insoluble impurities were filtrated through the vacuum filtration with membrane filter.
- Twice recrystallization process was performed
- Evaporation of water and cooling down the solution and filtration
- Washing the obtained crystals by cold ethanol and successful drying of crystals

ICP-MS measurement

- Content of impurities(K, Sr, Ba, Th, U, and Pb) in initial and purified NaI powder was measured by Inductively Coupled Plasma Mass Spectrometer analysis.

$$DF = \frac{Concentration\ of\ impurity\ in\ initial\ product}{Concentration\ of\ impurity\ in\ final\ product}$$

Results and Discussion

Table 1. Concentration of impurities of Crystal and Astro grade NaI powder

Sample	Unit	Ba^{138}	K^{39}	Pb^{208}	Sr^{88}	Th^{232}	U^{238}
Initial Crystal grade	ppb	7.14	45.07	3.30	0.90	<0.10	<0.10
Purified Crystal grade		0.62	6.04	0.81	<0.3	<0.10	<0.10
D.F		**11.5**	**7.5**	**4**	**> 3**	**-**	**-**
Initial Astro grade		0.60	4.51	0.93	<0.30	<0.10	<0.10
Purified Astro grade		<0.3	<1.0	<0.4	<0.3	<0.10	<0.10
D.F		**> 2**	**> 4.5**	**> 2**	**-**	**-**	**-**

Table 2. Concentration of impurities in initial NaI powder and decontamination factors after experiment

Sample	Unit	Ba^{138}	K^{39}	Pb^{208}	Sr^{88}	Th^{232}	U^{238}	Efficiency
Initial NaI powder (TG)	ppb	2591.8	180000	5.67	65.67	<0.10	<0.10	
1st recrystallized NaI		25.53	6280.16	0.36	0.65	<0.10	<0.10	**52.8 %**
D.F.		**102**	**29**	**16**	**101**	**-**	**-**	
2nd recrystallized NaI		5.29	1305.21	0.15	0.15	<0.10	<0.10	**27.4 %**
D.F.		**490**	**138**	**38**	**432**	**-**	**-**	
NaI crystal from 2nd MS		226.53	2744.79	0.40	1.26	<0.10	<0.10	**16.8 %**
D.F		**11**	**66**	**14**	**52**	**-**	**-**	

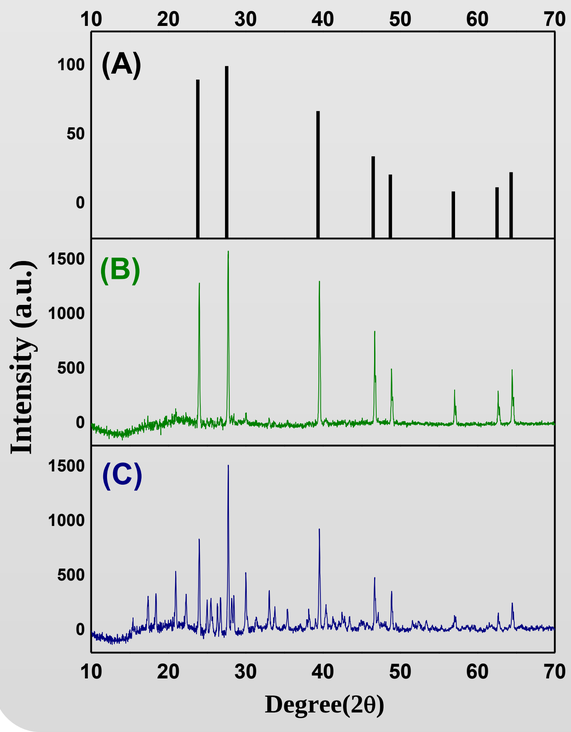


Figure 1. XRD data of initial and purified NaI powder. (A) initial NaI powder (technician grade) (B) after pre-process, 1st crystallized crystal. It has very similar peaks with NaI reference peaks. **(C) after 2nd crystallized crystal without pre-process.** It has similar peaks with NaI reference peaks but, it also have other small noise peaks

Summary & Plan

- **The recrystallization method had shown effective removing of the impurities, such as Ba, K, Pb, and Sr in the initial NaI powder. Product recovery efficiency were ~53 % after 1st crystallization and ~27 % after 2nd crystallization.**
- **When comparing the XRD of 1st crystal and 2nd crystal, immediately after pre-process crystal(1st crystal) had low noise peaks and very similar peak with NaI reference. Thus, to obtain only NaI crystal, the pre-process is essential.**
- **Our final goal of present study is the concentration level of K less than 10 ppb. In order to produce ultralow-background crystal, we achieved this goal level through the once or twice recrystallization of crystal grade NaI powder**