極低濃度ラドン測定システムの開発

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東京大学宇宙線研究所　平成22年度共同利用研究成果発表研究会
2010年12月17日(金曜日)

研究目的

背景:

SK実験の太陽ニュートリノ事象の主なBG

純水中^{222}Rn壊変生成物^{214}Biのβ 線

「純水中ラドン起源BG解明と低減」

ニュートリノ事象の解析閾値を下げる

技術的課題:

純水中極低ラドン脱気

脱気ガス中ラドン吸着・脱離

高感度ラドン濃度測定

純水中極低濃度ラドン測定システム開発
→0.1mBq/m^3

Methods

New Radon Detection System in Water :1)-5)

1)Degassing Radon in Purified Water:

New Air-Water Mixer:

Degassing Coefficient depend on Air/Water Flow Rate

2)Dehumidified Water Vapor:

Dehumidifier Efficiency by 4 Methods

3)Absorption Radon by Activated Charcoal:

Coefficient on Cooling Temperature:-90℃

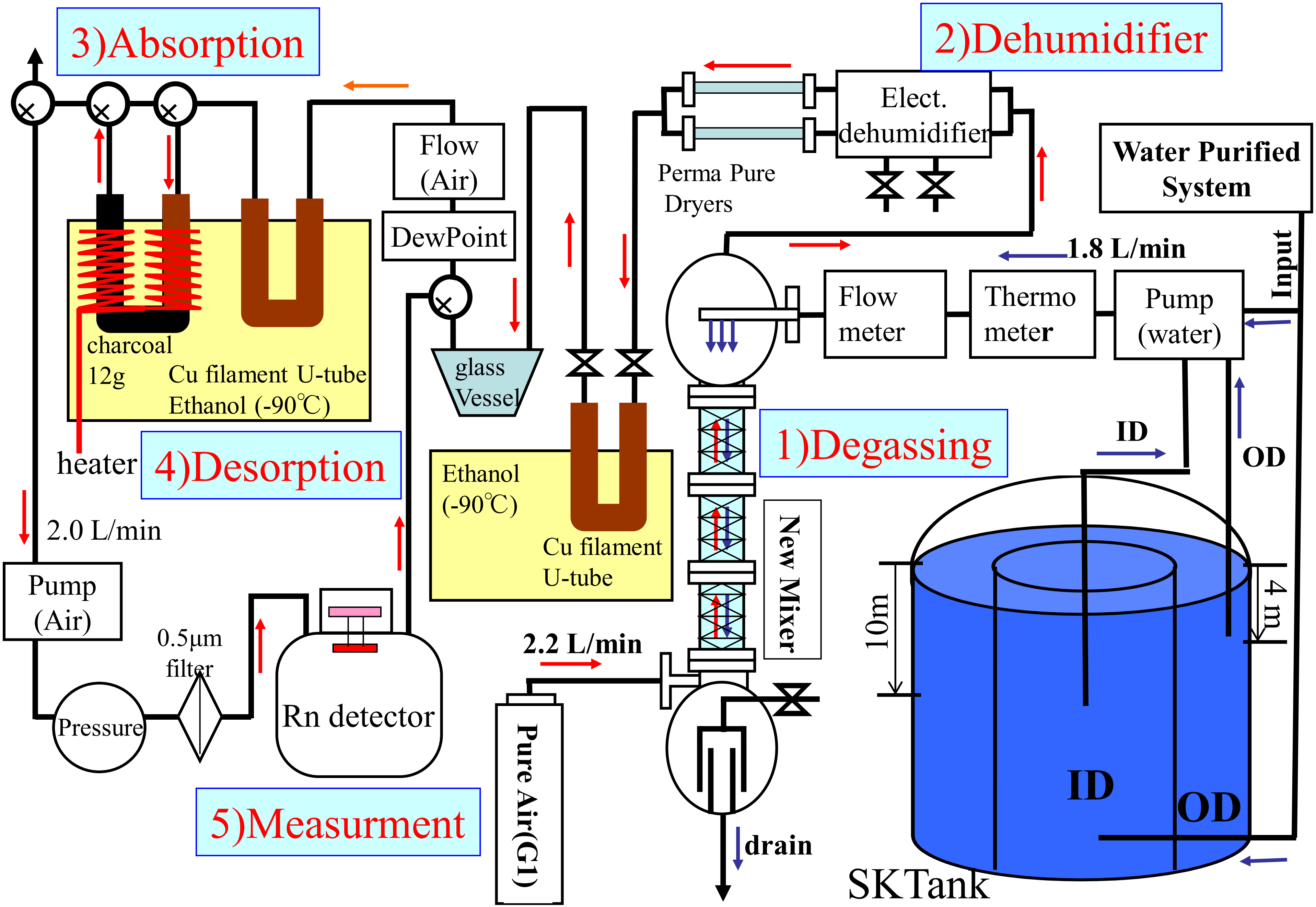
4)Desorption Radon by Activated Charcoal:

Coefficient on Heating Temperature :+250℃

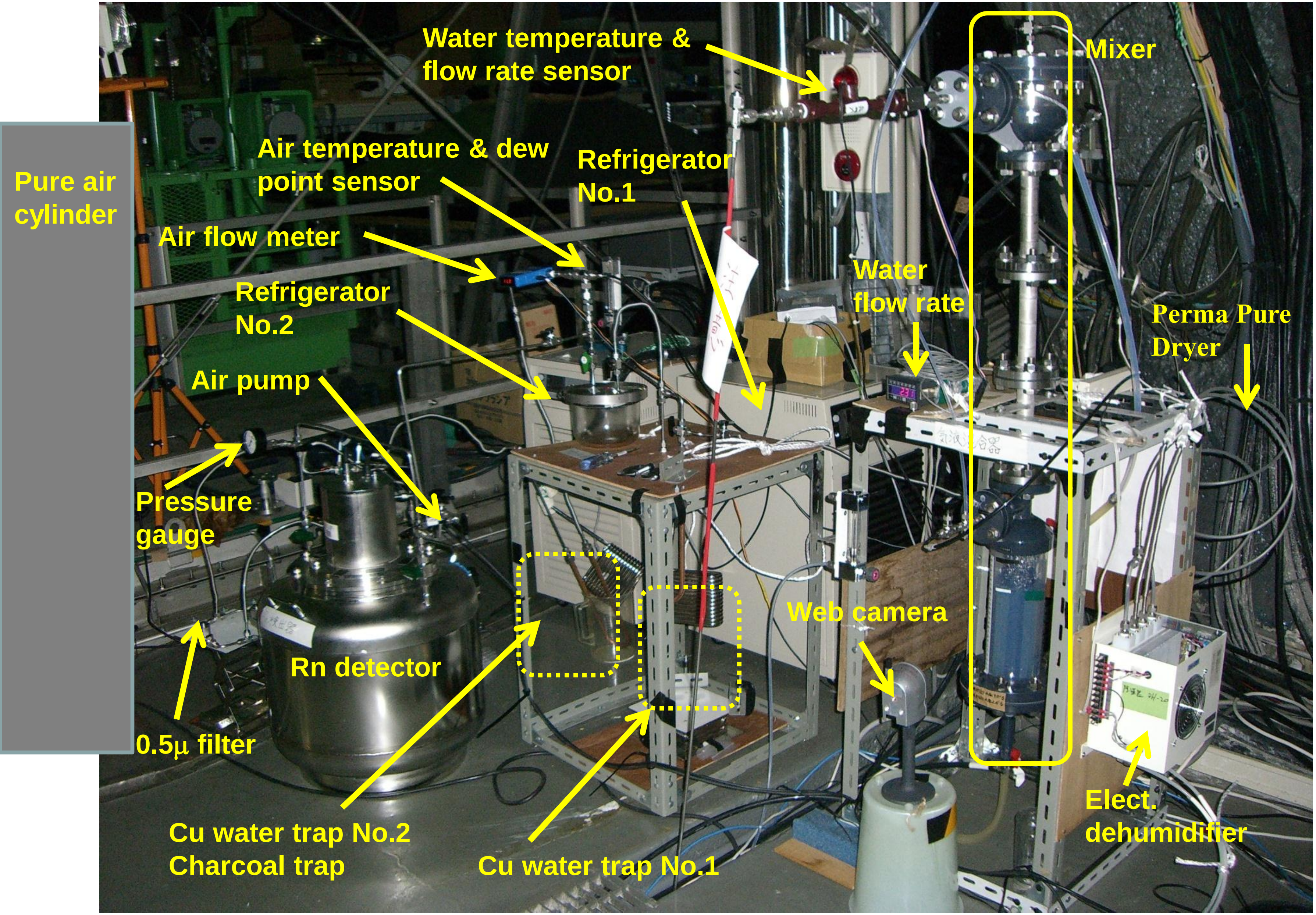
5)Measurement Radon

High Sensitivity Radon Detector with Electrostatic Collection of ^{222}Radon Daughters(^{214}Po): Detection Limits 5(mBq/m^3)

Radon Measurement System in SK Purified Water

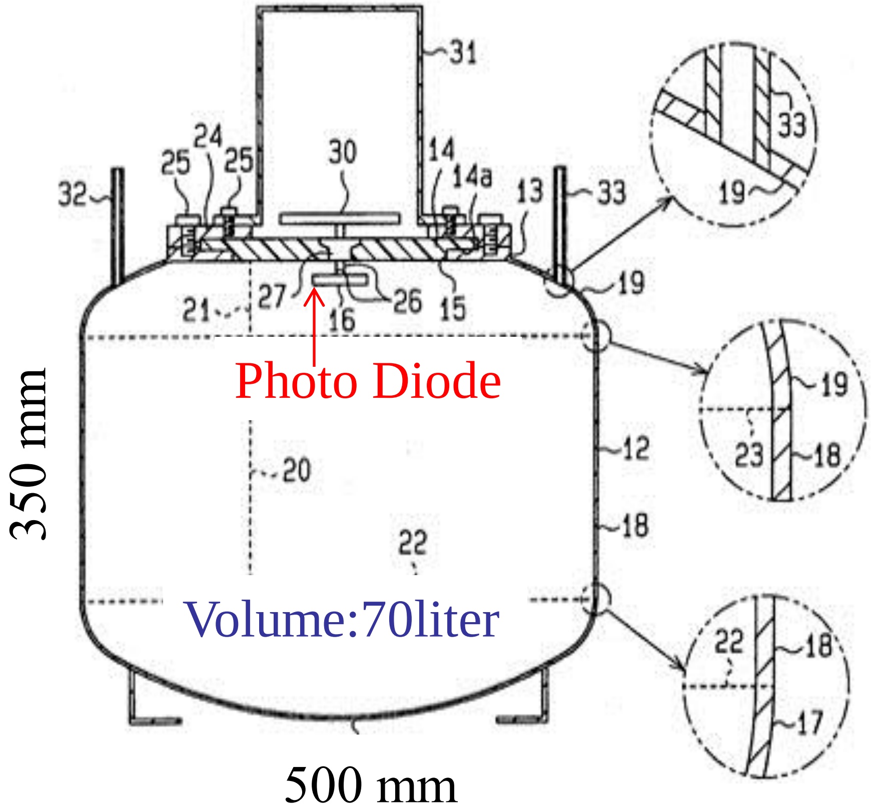


Radon measurement system

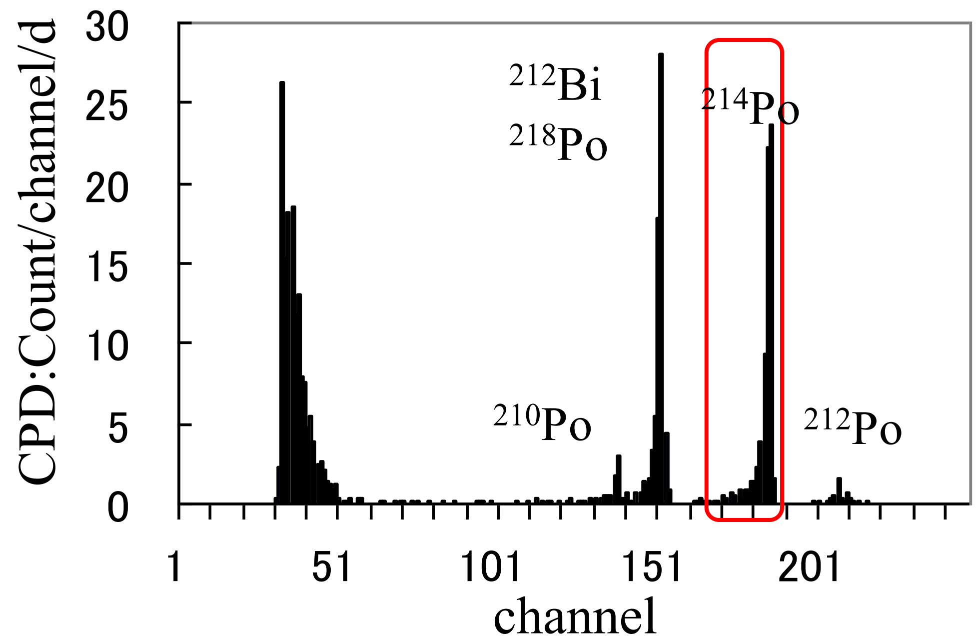


5)Measurement Radon

Electrostatic collection Radon Detector



Typical Pulse high distribution
2009/11/30-2009/12/11



- Sensor : PIN Photo-Diode
  α-rays energy separation
- Electro-polished stainless steel
- Electrostatic Voltage -2kV
- Detection Limits 6(mBq/m^3)

Detector Calibration by Source

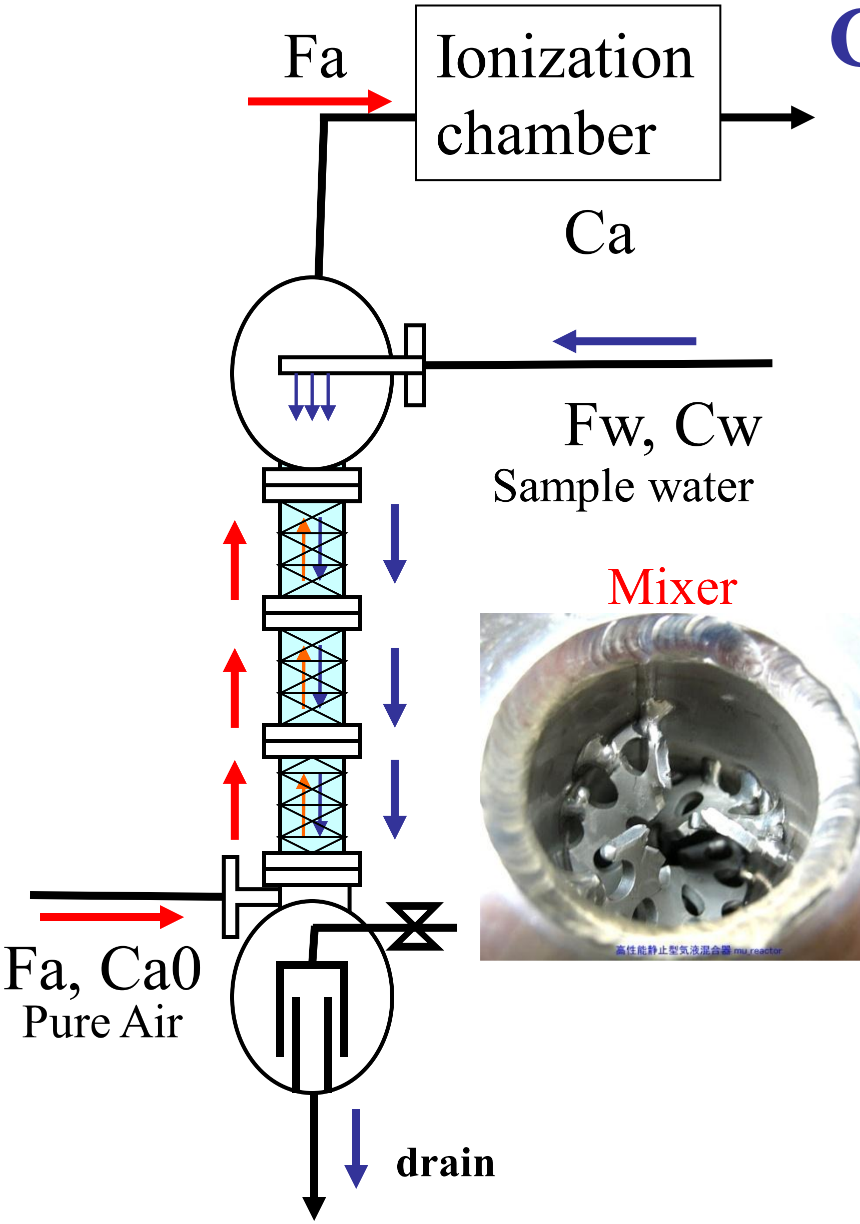
^{226}Ra(PYLON 78.3Bq)

CF=1.93±0.01[CPD/(mBq/m^3)]

AH:Absolute Humidity=0.011(g/m^3)

CF=2.03-1.08*SQRT(AH), AH<1.6g/m^3

1)Degassing Radon in Purified Water



$Cw=Ca(Fa/Fw+\alpha)$, $Ca0 >> Cw$

Fw : Water Flow=1.83L/min

Fa : Air Flow =2.32L/min

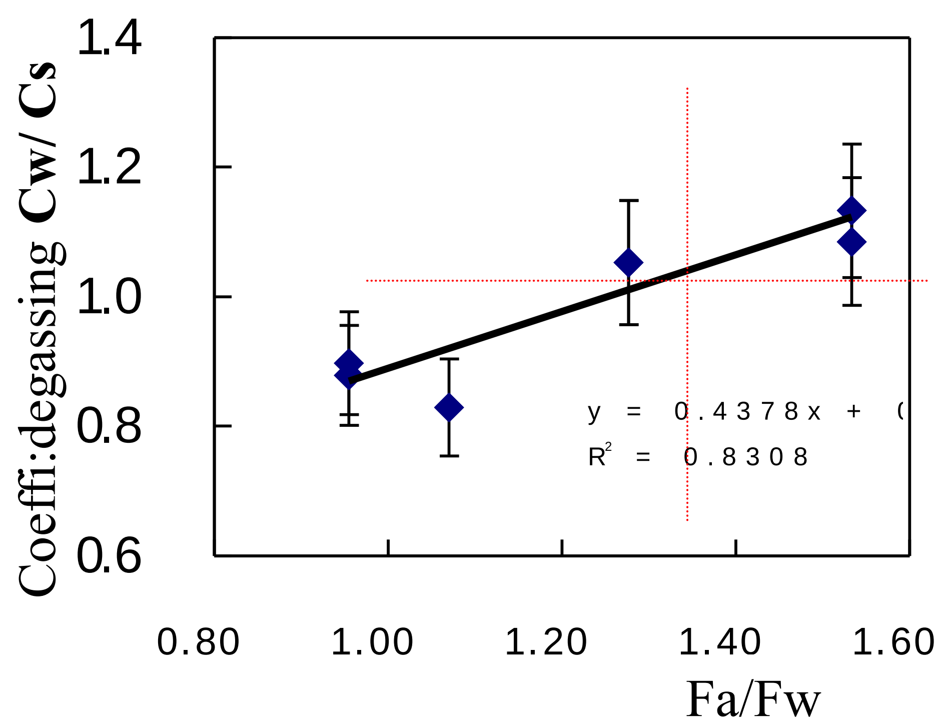
α : Solubility=0.24

Ca : Rn Concent. in Gas Phase

Cw : Rn Concent. in Liquid Phase

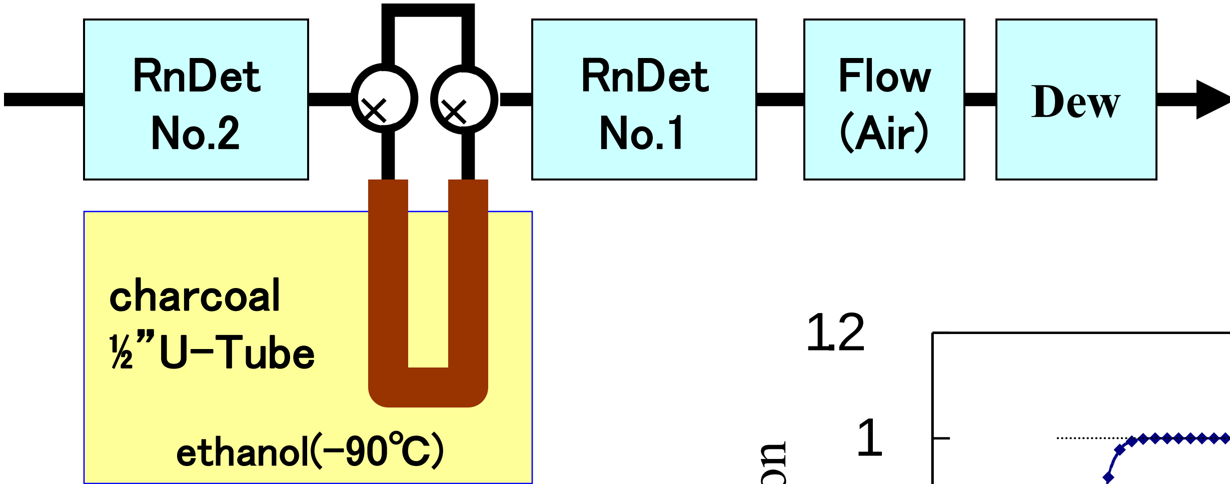
Cs : Water Rn Concent.(10Bq /L)

by Liquid Scintillation Method from ISO



3) Absorption Radon by Charcoal

Absorption Coefficient with Cooling Temp -90℃

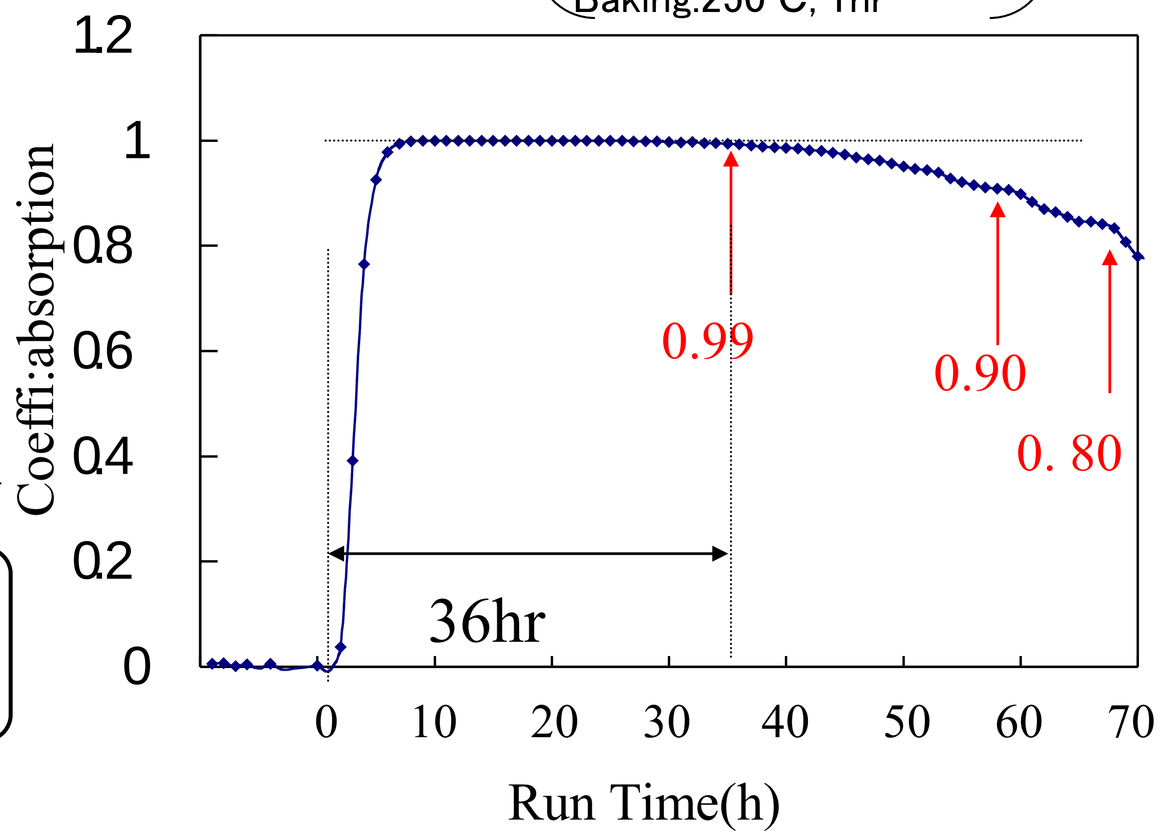


Exp conditions
Sample air : mine air (100 Bq/m^3)
DewPoint : -55℃
Fair : 2 L/min
charcoal : 24 g
Baking:250℃, 1hr

charcoal:
Mitsubishi Chemicals: G4-5

$$\text{Coeffi:absor} = 1 - \frac{CPH_1}{CPH_2 \cdot D}$$

CPH_1 : RnDetNo1:^{214}PoCPH
CPH_2 : RnDetNo2:^{214}PoCPH
D : Difference of Two Rn Det



Radon Measurement, OD, Input and ID Water

RUN	Sample	Time(hr)	Va (m^3)	Vw (m^3)	^{214}Po (CPD)	Ca (mBq/m^3)	Cw (mBq/m^3)
*1	BLANK	5	0.66	-	40.7	* 21.59	-
*2	BLANK	9	1.16	-	32.0	* 16.70	-
3	OD	5	0.67	0.55	105.4	55.32	7.08
4	OD	7	0.94	0.77	125.0	65.38	6.53
5	OD	9	1.21	1.00	169.0	88.20	7.34
6	Input	12	1.78	1.31	60.0	32.02	1.06
7	Input	27	3.92	2.95	87.0	45.64	1.03
* 8	ID	27	3.76	2.94	80.0	42.08	0.82

$$Cw = Ca\,(Va/Vw + \alpha)$$

$$Ca = (Vd/Va)(Ca' - C_{BG})/F$$

*without Flushed Pure Water

*preliminary

$F = Fmixer \times Fabsorption \times Fdesorption \times Fdecay$

$Ca' = CPD/CF$

$Va/Vw = Fa/Fw = 1.21 \sim 1.36$

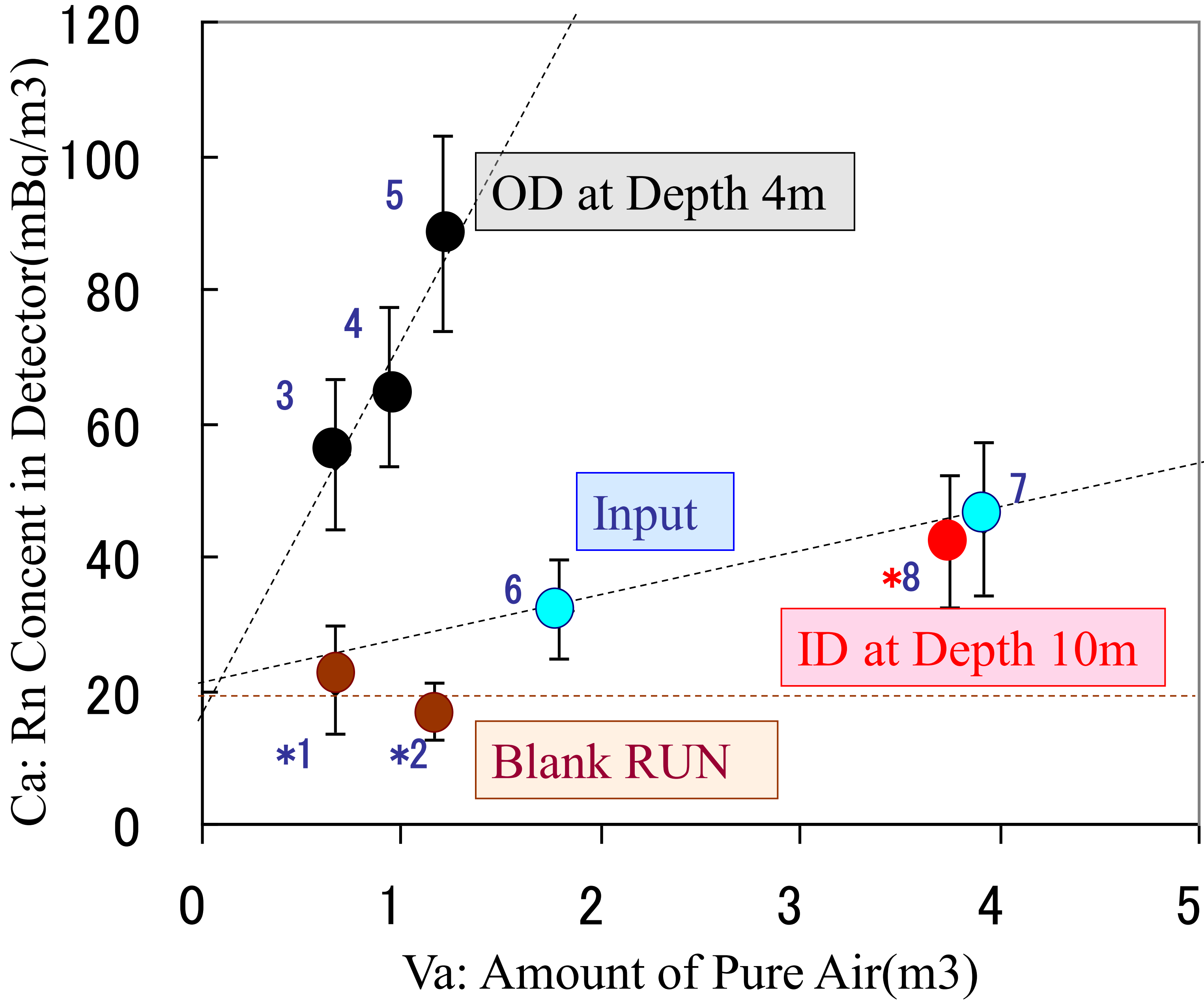
Enrichment: $Va/Vd = 10 \sim 56$

$Vd = 0.07 (m^3)$

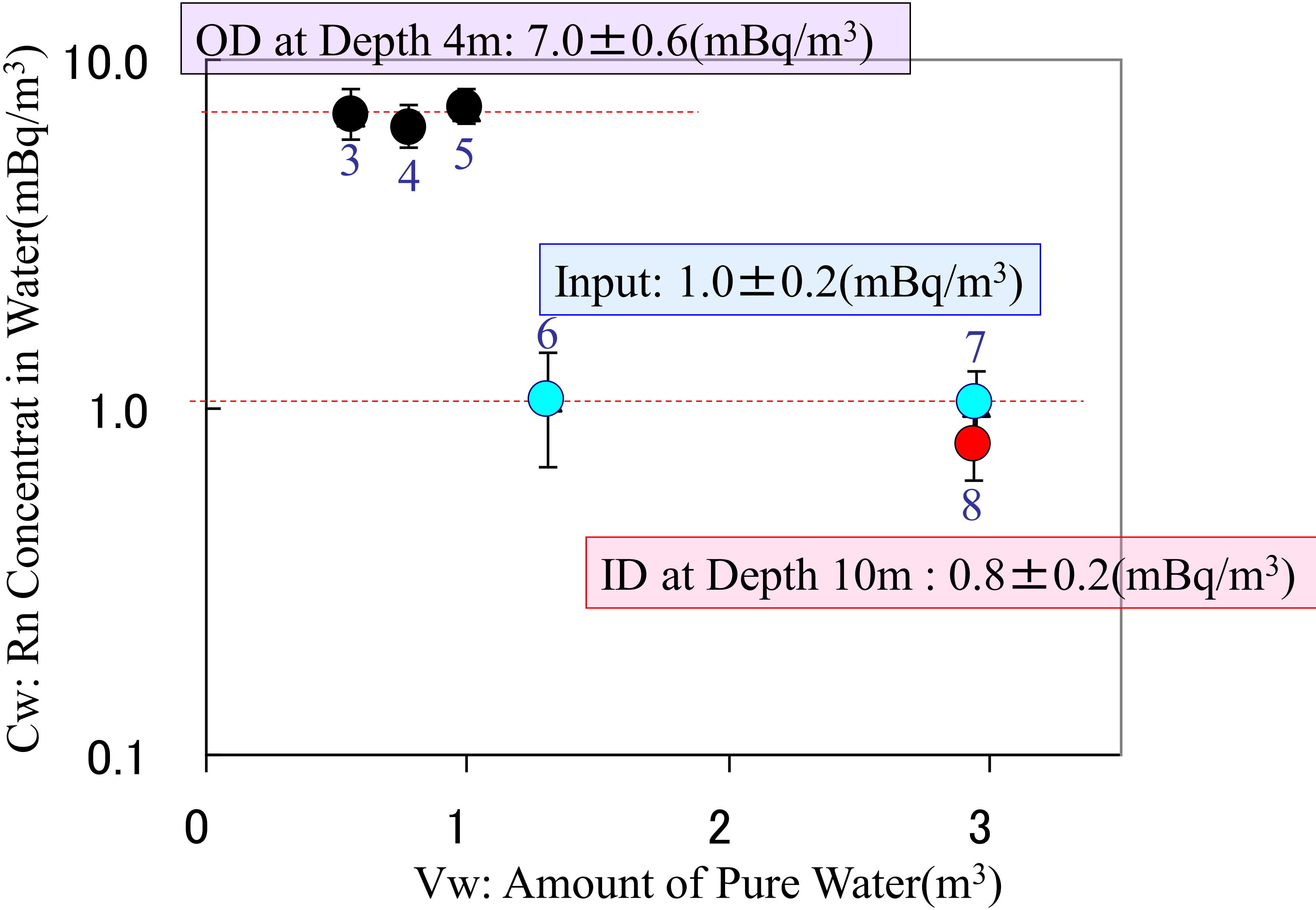
* $C_{BG} = 19 \pm 3 (mBq/m^3)$

$\alpha = 0.29$ ($Tw = 16$℃)

Radon Concentration in SK Pure Water



Radon Concentration in SK Pure Water



Summary

Development of Low Level Radon Concentration Measurement System in SK Pure Water, by using Air/Water New Mixer, and Absorption/Desorption of Activated Charcoal

This Results:

- **OD Water at Depth 4m: 7.0±0.6 (mBq/m^3)**
- **Input Water: 1.0±0.2(mBq/m^3)**
- **ID water at Depth 10m: 0.8±0.2 (mBq/m^3)**

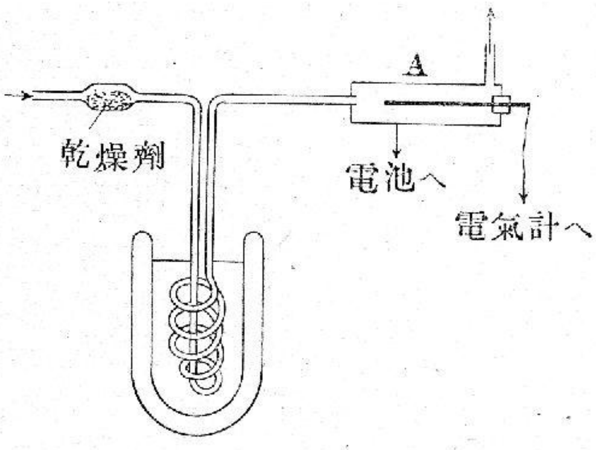
Phy.Lett.B452(1999)418-424, by Y.Takeuchi et al.

- Return Water <5.0 (mBq/m^3)
- Input Water <3.2 (mBq/m^3)
- ID at Tank Bottom 3-5 (mBq/m3)
- ID at Tank Central <1.4 (mBq/m^3)

今後の改良

- 気液混合器（排水・気密性）
- 配管系　swagelok →VCR
- 活性炭（エタノール-90℃）
  →蛇管（液体窒素）

常温では固体の器壁はRnを吸収しないが低温では非常に強くそれに凝固する。・・・冷凍器が液体空気の温度（－180℃）にある時エマナチオンは全部蛇管内に凝固する。冷凍器の温度を再び上げると電離箱内に電流が現われるのを確めることが出来る。これはRnに対しては－152℃で急に起る。



第 70 圖

マリーキュリー「放射能」１７６頁
９章放射性気体§４６．液体及び固体による吸収、溶解度、低温に於ける凝固