Kr Capture in Head-End Process of Pyroprocess

Seok-Min Hong*, Ahreum Han, Jae Hwan Yang, and Yung-Zun Cho

Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea

*seokminhong@kaeri.re.kr

1. Introduction

A substantial interest has been generated in an accumulation of spent fuel due to its energy and environmental issue [1]. To solve this issue, Korea Atomic Energy Research Institute (KAERI) has investigated a reprocessing technology, pyroprocessing, which not only reduces the accumulated spent fuel but also increases the efficiency of fuel cycle.

In head-end process of pyroprocessing, UO_2 pellets are prepared from a fuel bundle for electrochemical reduction while various radioactive gases are released from a spent fuel during thermal treatment. Among these gases, Kr is a harmful volatile gas which has a long half-life of ~11 years and high radioactivity, and thus it is strongly required to capture Kr [2]. Several approaches such as cryogenic distillation, absorption using solvents, and adsorption on solids have been conventionally applied to Kr capture. Of these methods, adsorption has many advantages as it provides low energy-consumption processes with easy regeneration. In Kr adsorption, adsorbents such as activated carbon and zeolites have been widely used [3].

2. Experimental Section

2.1 Adsorption Column

The adsorbents were degassed at 110 ^{o}C overnight for the removal of adsorbed water and impurities. The adsorption experiment was carried using a column of a diameter of 30 mm packed with ~20 g adsorbent. The flow rate was 126 cm^3 min^{-1} and the pressure was 1 atm. The feed gas contains few parts per millions (ppm) with Ar base. The temperature of the column maintained using ethanol heat exchanger.

2.2 Gas Analysis

The gas composition was measured using a gas chromatography (DS Science, Republic of Korea) equipped with a pulsed discharge detector (PDD). He was used as a carrier gas and the 30 m of GC column (ValcoPLOT Molesieve 5A) was installed. Prior to the adsorption test, the 100 and 300 ppm Kr balanced Ar was used as standard gases.

2.3 Breakthrough Curve

In order to obtain adsorption capacity, the breakthrough time was used as:

$$q = \frac{F}{M}\int_0^{t_b}(Co - C)dt \quad (1)$$

where q represent adsorption capacity (mmol kg^{-1}), F is a flow rate (cm^3 min^{-1}), M is a mass of adsorbent (g), t_b is a breakthrough time (min). Co and C are initial and measured concentration, respectively.

3. Adsorption Test

3.1 Adsorption Column Installation

The adsorption column was installed as shown in Fig. 1. The 200 ppm Kr balanced with Ar was used as feed gas and the constant amount of feed flows from the bottom to the upper part of the column and finally reached to the GC as displayed in Fig. 2.

3.2 Adsorption performances

Dynamic results were obtained through composition of gas using GC, and the adsorption performances such as working capacities, equilibrium capacity, and kinetic. Furthermore, the effects of adsorption condition on the adsorption capacities were investigated. These parameter effects will be further applied in optimizing adsorption process.

4. Conclusion

Kr adsorption process was designed and tested using a packed bed column filled with adsorbents. The Kr adsorption performances were determined from breakthrough curves obtained from a GC, and the effects of capturing conditions on adsorption capacities were investigated.

Fig. 1. Adsorption column.

Fig. 2. Gas chromatography equipped with PDD.

REFERENCES

[1] L. Deliere, B. Coasne, S. Topin, C. Greau, C. Moulin, D. Farrusseng, “Beakthrough in Xenon capture and purification using adsorbent-supported silver nanoparticles”, Chemistry: A European Journal, 2, 9660–9666 (2016).

[2] M. Greenhalgh, T. G. Garn, J. D. Law, “Development of a hydrogen mordenite sorbent for the capture of krypton from used nuclear fuel reprocessing off-gas streams”, Journal of Nuclear Science and Technology, 51, 476481 (2014).

[3] K. Munakata, S. Kanjo, S. Yamatsuki, A. Koga, D. Ianovski, “Adsorption of noble gases on silver-mordenite”, Journal of Nuclear Science and Technology, 40, 695−697 (2003).