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Measurement of Ce(IV) Concentration in Foam Decontaminant containing Fluorosurfactant

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1. Introduction

Facilities that handle radioactive materials deteriorate with age after a long period of operation. Consequently, a decontamination technology has been developed to prevent the proliferation of radioactive materials and reduce the radiation exposure of operators while at work. In particular, foam decontamination technology can significantly reduce the radioactive waste produced after decontamination for large equipment or facilities, because more than 90% of the decontaminating materials used with this technology consist of gases[1-3]. To improve the stability of the foam, surfactants and inorganic materials such as nanoparticles can be added.

A nanoparticle-based foam decontaminant is composed of a surfactant and nanoparticles for the generation and maintenance of foam, and a chemical decontamination agent made of Ce(IV) dissolved in nitric acid. Ce(IV) will be reduced to Ce(III) through the decontamination process. Oxidizing the cerium (III) can be reused as a decontamination agent, Ce(IV). Oxidation treatment technology by ozone uses its strong oxidizing power [4]. It can be regarded as an environmentally friendly process, because ozone cannot be stored and transported like other industrial gases (because it quickly decays into diatomic oxygen) and must therefore be produced on site, and used ozone can be decomposed immediately. A concentration analysis of Ce(IV) in foam decontaminant containing a surfactant is necessary prior to the derivation of optimal conditions for the regeneration of Ce(III) through ozonation treatment.

A UV spectrometric method using the absorbance or potentiometric method with a potential difference in Ce(III)/Ce(IV), or a potentiometric titration method using Fe (II), can be used for a Ce(IV) concentration analysis. A UV spectrometric method has a problem receiving the influence of the surfactant, and a potentiometric method is difficult to use because of the problem of an insignificant change in the potential difference value of the Ce(III)/Ce(IV).

Thus, the present study was undertaken to determine whether the potentiometric titration method can be used for an analysis of the Ce(IV) concentration in the nanoparticle-based foam decontaminant containing surfactant.

2. Methods and Results

2.1 Experimental Methods

The potential change appears as a titration with a 0.1M Fe(II) solution (ammonium Ferrous (IronII) Sulfate, 99%, Aldrich) of a mixture of 2M sulfuric acid (or 2M nitric acid) and 0.1M Ce(IV) (Cerium(IV) Ammonium Nitrate, 99.5%, Alfa Aesar) were measured using an ORP electrode (Epoxy Low Maintenance ORP/ATC Triode No. 9179 BNMD), and were analyzed for the concentration of Ce(IV).

The potential change was measured according to the variation of surfactant concentration in the range of 0.5-1.5% in order to determine whether the potentiometric titration method is valid for the analysis of Ce(IV) concentration in nanoparticle-based foam decontaminant containing anionic fluorosurfactant Zonyl TBS (Dupont), and this was compared with the case in which TBS was not contained.

In addition, a mixture of a 0.1M Ce(IV) solution and a 2M nitric acid solution was tested in accordance with the potential value changes to examine whether the potentiometric titration method is effective with an acid medium change. It was compared with the behavior in a 2M sulfuric acid medium.

2.2 Results & Discussion

It was investigated whether the potentiometric titration method can be used for an analysis of the Ce(IV) concentration, since the analysis on the concentration of Ce(IV) present in the surfactant is difficult by conventional methods such as a UV colorimetric or potentiometric method. In this case, the reaction of Ce (IV) and Fe(II) is as follows:

$$Ce^{4+} + Fe^{2+} \rightarrow Ce^{3+} + Fe^{3+}$$

The potential change value was measured in a surfactant concentration range of 0.5 to 1.5% in order to search whether the potentiometric titration method is valid for an analysis of Ce(IV) concentration in nanoparticle-based foam decontaminant containing TBS surfactant.

As shown in Fig. 1, the same inflection point in the potential appeared at the point at which 20ml of a Fe(II) solution was added, regardless of the concentration of TBS. These results were the same as in the case of a

non-addition of TBS. Therefore, it was found that the TBS surfactant has no effect on an analysis of Ce(IV) concentration by the potentiometric titration method using Fe(II).

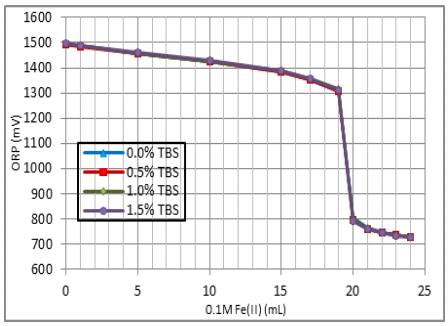

Fig. 1. Potentiometric titration curves using Fe(II) according to TBS concentration of 0~1.5%.

Ce(IV) and Fe(II) is present in the most stable state at 1-2M sulfuric acid. Since the nanoparticle-based foam decontaminant used in this study is made up of 2M nitric acid, it was examined whether the potentiometric titration method in a 2M nitric acid medium is effective for an analysis of Ce(IV) concentration.

As shown in Fig. 2, the same inflection point appeared in the potential at which 20ml of a Fe(II) solution was added, in both 2M nitric acid and 2M sulfuric acid medium. Thus, it is possible to determine the Ce(IV) concentration by the potentiometric titration method using Fe(II) in a 2M nitric acid medium.

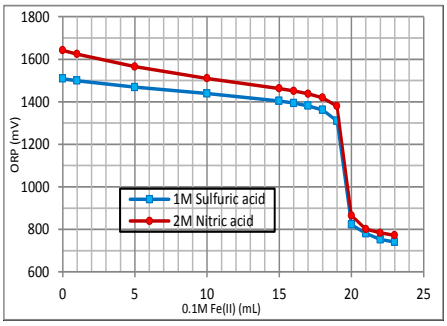

Fig. 2. Potentiometric titration curves using Fe(II) according to the acid medium type.

3. Conclusions

Potentiometric titration with Fe(II) was able to effectively analyze the concentration of Ce(IV) in the nanoparticle-based foam decontaminant containing surfactant regenerated through ozonation treatment. Also it was confirmed that a Ce(IV) concentration analysis is valid by this potentiometric titration method since it exhibits the same behavior in the different acid medium.

Therefore, it will be effectively used for the Ce(IV) concentration measurement, in relation to the subsequent research on the derivation of optimal conditions for the regeneration of Ce(III) through ozonation treatment.

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