Chemistry - PI 24

ISOTOPIC SEPARATION - GENERAL

OBJECTIVES

1. Define in mathematical terms "elementary separation factor" and very briefly note the meaning of each term in the definition.

2. State the basic principles behind the two isotopic separation processes:

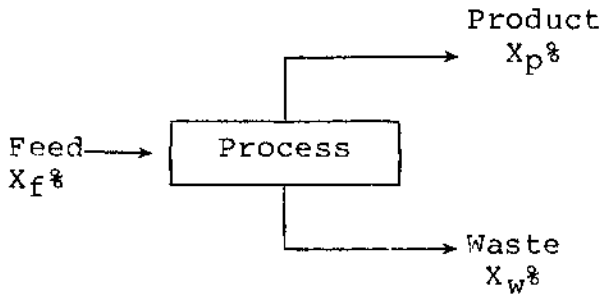
   i) Distillation
   ii) Exchange Reactions

   and state whether the process is chemical or physical.

This module will address the principles behind the methods used for isotopic separation in NGD.

The separation of isotopes is used in the production of heavy water (isolation of $_1H^2$ from mixtures of $_1H^1$ and $_1H^2$). Enrichment of fuel (separation of $_{92}U^{235}$ from $_{92}U^{238}$) is another isotopic separation process (but not done by NGD).

In any separation process, a measure of the efficiency is the **separation factor.** The following diagram is a schematic of a generalized separation process.



For the desired isotope, the feed contains x_f%, the product x_p% and the waste x_w%.

Separation factor is defined as:

$$S = \frac{x_p}{x_w}$$

For a process to be viable, the separation factor must be greater than unity. Where the separation factor is close to unity several separation stages may be employed in a cascade fashion to improve the net separation.

There are several viable methods for isotopic separation; some of which are:

i) Distillation
ii) Exchange Reactions
iii) Gaseous Diffusion
iv) Electrolysis
v) Centrifugation.

Of these, NGD uses only Distillation and Exchange Reactions.

i) Distillation

As a general rule, isotopic species of the same element or compound have different vapour pressures (and boiling points) so that partial separation by simple distillation and even better separation by fractional distillation (see 11-3) is a theoretical process.

Indeed the finishing process at Bruce Heavy Water Plant and the heavy water upgraders used by NGD are fractional distillation columns.

ii) Exchange Reactions

Most isotopic separation methods depend on differences in the physical properties of the isotopes. Exchange reactions, on the other hand, are based on the different reactivities (a chemical property) of the isotopes. Simply stated; if an element has, for example, 2 isotopes and a third element is available for a chemical reaction, one of the isotopes will have more "desire" to enter the reaction and compete harder for the third element.

The most important reaction that we are concerned with in NGD is the following equilibrium of water and hydrogen sulphide:

$$H_2O\ (\ell) + HDS\ (g) \rightleftharpoons HDO\ (\ell) + H_2S\ (g)$$

which is the exchange reaction used in the enriching portion of the BHWP (see module 11-2).

Electrolysis

The basis of isotope separation by electrolysis for hydrogen and deuterium is that electrolysis of aqueous solutions results in preferential evolution of the lighter isotope, hydrogen, at the cathode. Consequently, the liquid phase becomes enriched in deuterium.

Commercial electrolysis plants have many stages and the gas from latter stages, itself rich in deuterium is burned and used as feed for upstream cells.

NPD NGS at Rolphton sends its downgraded heavy water to CRNL for upgrading by electrolysis.

PRACTICE EXERCISES

1. Write a mathematical definition of "elementary separation factor", define each term in the expression.

2. Briefly state the principles behind:

   (a) Exchange Reactions
   (b) Distillation

   for the separation of isotopes. State whether each method is chemical or physical.

   Write your answers in your own words in the space below then compare your work to the data in the text of the module.

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