

## CONTENTS

|                                    | Page        |
|------------------------------------|-------------|
| <b>LIST of TABLES .....</b>        | <b>vi</b>   |
| <b>LIST OF FIGURES .....</b>       | <b>viii</b> |
| <b>LIST of ABBREVIATIONS .....</b> | <b>xi</b>   |
| <b>SUMMARY .....</b>               | <b>xiii</b> |

### CHAPTER 1

#### INTRODUCTION

|                                                                        |           |
|------------------------------------------------------------------------|-----------|
| <b>1.1. General considerations .....</b>                               | <b>1</b>  |
| <b>1.2. Nuclear fission reactions .....</b>                            | <b>2</b>  |
| 1.2.1. Definition of the nuclear fission process .....                 | 2         |
| 1.2.2. Radioactive decay of the initial fission fragments .....        | 4         |
| 1.2.3. Specific activities of $^{235}\text{U}$ -fission isotopes ..... | 5         |
| 1.2.4. Relative importance and uses of the fission products .....      | 6         |
| <b>1.3. Uranium targets .....</b>                                      | <b>7</b>  |
| 1.3.1. Irradiation behavior of uranium .....                           | 7         |
| 1.3.2. Cooling of irradiated uranium targets .....                     | 10        |
| 1.3.3. Dissolution of irradiated uranium targets .....                 | 10        |
| <b>1.4. Chemistry of uranium and fission products .....</b>            | <b>21</b> |
| 1.4.1. Chemistry of uranium .....                                      | 21        |
| 1.4.2. Chemistry of fission products .....                             | 22        |
| <b>1.5. Chemical separation concepts.....</b>                          | <b>37</b> |
| 1.5.1. Criteria for selection of the separation process .....          | 37        |
| 1.5.2. Topics of important separation processes .....                  | 38        |
| 1.5.2.1. Precipitation methods .....                                   | 38        |
| 1.5.2.1.1. Conditions affecting precipitation .....                    | 38        |
| 1.5.2.1.2. Practical limitations of precipitation methods .....        | 39        |
| 1.5.2.2. Solvent extraction methods .....                              | 39        |

|                                                                      | <b>Page</b> |
|----------------------------------------------------------------------|-------------|
| <b>2.2. Equipments and apparatuses .....</b>                         | <b>75</b>   |
| 2.2.1. Equipments .....                                              | 75          |
| 2.2.2. Apparatuses .....                                             | 75          |
| <b>2.3. Preparation and irradiation of the uranium targets .....</b> | <b>79</b>   |
| <b>2.4. Chemical processing .....</b>                                | <b>79</b>   |
| 2.4.1. Digestion of the irradiated uranium targets .....             | 79          |
| 2.4.2. Separation and recovery of radioiodine .....                  | 81          |
| 2.4.3. Separation and recovery of radioruthenium .....               | 81          |
| 2.4.4. Batch separation of Sr, Ba, La, and Ce radionuclides .....    | 82          |
| 2.4.5. Batch separation of Zr, Nb, Te, and Np radionuclides .....    | 82          |
| 2.4.6. Separation and recovery of radiocesium .....                  | 82          |
| 2.4.7. Recovery of radiomolybdenum .....                             | 83          |
| <b>2.5. Quality control investigations .....</b>                     | <b>83</b>   |
| 2.5.1. Separation and recovery yields .....                          | 83          |
| 2.5.2. Radionuclidic purity .....                                    | 86          |
| 2.5.3. Radiochemical purity .....                                    | 86          |
| 2.5.4. pH-value .....                                                | 87          |
| <br><b>CHAPTER 3</b><br><b>RESULTS AND DISCUSSION</b>                |             |
| <b>3.1. Preparation and choice of the uranium target .....</b>       | <b>88</b>   |
| 3.1.1. Target wrapper and irradiation can .....                      | 88          |
| 3.1.2. Uranium targets .....                                         | 89          |
| <b>3.2. Digestion of the irradiated uranium targets .....</b>        | <b>92</b>   |
| 3.2.1. Advantages of alkali digestion over acid dissolution .....    | 92          |
| 3.2.2. The digestion technique .....                                 | 93          |
| <b>3.2. Production of radioiodine .....</b>                          | <b>98</b>   |
| 3.3.1. Separation technique .....                                    | 104         |
| 3.3.2. Quality control of the $^{131}\text{I}$ product .....         | 107         |

|                                                                                 | <b>Page</b> |
|---------------------------------------------------------------------------------|-------------|
| 3.3.2.1. Separation and recovery yields .....                                   | 107         |
| 3.3.2.2. Radionuclidic purity .....                                             | 110         |
| 3.3.2.3. Radiochemical purity .....                                             | 111         |
| 3.3.2.4. pH-value of the product solution .....                                 | 114         |
| 3.3.2.5. Radioactivity and specific activity .....                              | 114         |
| 3.3.3. Precautions of separation, handling, and<br>storage of radioiodine ..... | 116         |
| <b>3.4. Production of radoruthenium .....</b>                                   | <b>118</b>  |
| 3.4.1. Separation technique .....                                               | 121         |
| 3.4.2. Quality control of the $^{103}\text{Ru}$ product .....                   | 123         |
| 3.4.2.1. Separation and recovery yields .....                                   | 123         |
| 3.4.2.2. Radionuclidic purity .....                                             | 126         |
| 3.4.2.3. pH-value of the product solution .....                                 | 127         |
| 3.4.2.4. Radioactivity and specific activity .....                              | 127         |
| 3.4.3. Precautions of separation of radoruthenium .....                         | 127         |
| <b>3.5. Batch separation of Sr, Ba, La, and Ce radionuclides .....</b>          | <b>129</b>  |
| 3.5.1. Separation technique .....                                               | 129         |
| 3.5.2. Radiometric analysis of the formed precipitate .....                     | 132         |
| <b>3.6. Batch separation of Zr, Nb, Te, and Np radionuclides .....</b>          | <b>139</b>  |
| 3.6.1. Separation technique .....                                               | 139         |
| 3.6.2. Radiometric analysis of the formed precipitate .....                     | 142         |
| <b>3.7. Production of radiocesium .....</b>                                     | <b>151</b>  |
| 3.7.1. Separation technique .....                                               | 154         |
| 3.7.2. Quality control of the $^{137}\text{Cs}$ product .....                   | 157         |
| 3.7.2.1. Separation and recovery yields .....                                   | 157         |
| 3.7.2.2. Radionuclidic purity .....                                             | 160         |
| 3.7.2.3. Radioactivity and specific activity .....                              | 160         |

|                                                              | Page       |
|--------------------------------------------------------------|------------|
| <b>3.8. Production of radiomolybdenum .....</b>              | <b>162</b> |
| 3.8.1. Recovery of $^{99}\text{Mo}$ .....                    | 166        |
| 3.8.2. Quality control of the $^{99}\text{Mo}$ product ..... | 166        |
| 3.8.2.1. Recovery yield .....                                | 166        |
| 3.8.2.2. Radionuclidic purity.....                           | 169        |
| 3.8.2.3. pH-value of the product solution .....              | 169        |
| 3.8.2.4. Radioactivity and specific activity .....           | 169        |
| <b>REFERENCES .....</b>                                      | <b>173</b> |