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# Ion beam Activation of $^{nat}$Cu, $^{nat}$Ti, $^{nat}$Ni and Measurement of Production Cross-Sections at Low Energy (<10MeV)

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## Abstract

In this study we have investigated the production cross-sections of $^{nat}$Cu(p,x), $^{nat}$Ti(p,x), $^{nat}$Ni(p,x) and $^{nat}$Cu(α,x), $^{nat}$Ti(α,x), $^{nat}$Ni(α,x) reactions within low energy range using Stack foil activation technique.The samples were activated in vacuum at 5 MV tandem (Pelletron) accelerator installed at National Centre for Physics (NCP), Islamabad, Pakistan. The stopping and range of ions in matter (SRIM) software was used to calculate the energy degradation due to bombardment of ion beam on target material. The reaction products were identified with the help of Off-line gamma ray spectroscopy system connected with Genie 2000 software.The data analysis revealed the production of different radioisotopes that have valuable importance in the field of medical and industrial applicationof radioisotopes. The measured results were verified by comparing them with earlier reported data as well as with the theoretical values obtained from the model calculations based on Talys-1.9code. The present research work results will assume a significant part in advancement of the writing information base for clinical and mechanical radioisotopes carried by proton and alpha-beam activation.

**Keywords:** Charge Particles Reaction, Foil Activation Technique, off-line Gamma ray spectroscopy, Cross-section measurement

## *Introduction*

Activation techniques required incident beam and target material. The incident beam is specified according to their nature and energy ranges while target material is specified according to their required chemical and nuclear properties. Natural copper, titanium and nickel are model target material due to their occurrence, physical, nuclear and chemical properties. Many researchers have reported ion beam activation of$^{nat}$Ti,$^{nat}$Cu,$^{nat}$Ni foils at high energies[1-3] & some studied in medium and low energy ranges[4-5] but there is not enough experimental data of reactions cross-section at low energies(<10MeV). Therefore, one of objective of present research work is to measure cross-sections of the nuclear reaction products used for medical, industrial, and agricultural applications via ion beam activation technique.

## *Experimental*

### *Preparation of the materials*

Proton ($H^+$) and alpha ($^4He^+$) ion beams were used to activate the selected target materials ($^{nat}$Cu, $^{nat}$Ti, $^{nat}$Ni) of thickness 0.002cm at 6MeV and 9.6MeV respectively. The target material was placed in the beam line of 5MV Palletron Tandem Accelerator which is limitized at low energies and that was facilitated by National Centre for Physics (NCP), Islamabad, Pakistan. Two endstations are available at 15$^o$ and 30$^o$ beam lines. The 15$^o$ -endstation is meant for the materials characterization while the 30$^o$ -endstation is used for the nuclear physics experiments. [6].The sample can be activated for an hour or two, depending on that experimental condition.The activation was monitored on the computer outside the accelerator hall. Start Time of Activation, Irradiation Time, End of Bombardment Time (EOB), Energy of Ions Beam($H^+$~6MeV&$^4He^+$~9.6MeV),Beam Current(87nA-250nA), Charge (μC) parameters were noted during the experiment. After activation the target foil was carefully separated from sample holder with the help of forceps and inserted in polythene bag which was marked with sample specification. The polythene bag containing sample was attached at the centre of acrylic plate. The acrylic plate was then positioned in front of HPGe detector at different distances for activity measurement. The sample container was shielded with lead to avoid background radiation.

## *Results and discussion*

The cross-section values were measured for residual radionuclides that were produced by the bombardment of proton and alpha beams on $^{nat}$Cu,$^{nat}$Ni, $^{nat}$Ti. are given in table-1 -2.The gamma counting were taken again and again at different cooling time to avoid the contamination among gamma peak for different isotopes.The beam flux was calculated by faraday cup while energy calibration of incident energy was based on the internal system of 5MV Tandemaccelerator.

**Table 1.** Cross-Section Data of Reaction Productsin $^{nat}$Cu(p,x), $^{nat}$Ni (p,x) ,$^{nat}$Ti(p,x) Reactions

| Reactions | Energy(MeV) | Cross-Section(mb) |
|---|---|---|
| $^{nat}$Cu(p,x)$^{63}$Zn | 6±0.369 | 103.31±6.33 |
| | 4.856±0.405 | 57.41±6.39 |
| $^{nat}$Cu(p,x)$^{65}$Zn | 6±0.369 | 95.88±5.88 |
| | 4.856±0.405 | 44.95±5.51 |
| $^{nat}$Ti(p,x)$^{48}$V | 6±0.212 | 130.39±10.12 |
| | 5.383±0.212 | 128.65±10.12 |
| $^{nat}$Ni(p,x)$^{55}$Co | 6±0.390 | 0.52±0.04 |
| | 4.786±0.433 | 0.16±0.01 |
| $^{nat}$Ni(p,x)$^{60}$Cu | 6±0.390 | 3.91±0.39 |
| | 4.786±0.433 | 1.79±0.17 |
| $^{nat}$Ni(p,x)$^{61}$Cu | 6±0.390 | 2.63±0.22 |
| | 4.786±0.433 | 1.55±0.12 |

**Table 2.** Cross-Section Data Reaction Products in $^{nat}$Cu (α, x), $^{nat}$Ni (α, x), $^{nat}$Ti(α,x) Reactions

| Reactions | Energy(MeV) | Cross-section(mb) |
|---|---|---|
| $^{nat}$Cu(α,n) $^{66}$Ga | 9.6±0.32 | 3.95±0.62 |
| $^{nat}$Cu(α,γ) $^{67}$Ga | 9.6±0.32 | 0.20±0.038 |
| $^{nat}$Cu(α,n) $^{68}$Ga | 9.6±0.32 | 3.42±0.53 |
| $^{nat}$Ti(α,n) $^{49}$Cr | 9.6±0.16 | 1.82± 0.27 |
| | 3.33±0.18 | 1.15± 0.18 |
| $^{nat}$Ni(α,γ) $^{62}$Zn | 1.08±0.38 | 0.003± 0.0002 |
| | 9.6±0.50 | 0.075± 0.004 |
| $^{nat}$Ni(α,n) $^{63}$Zn | 1.08±0.38 | 0.054±0.002 |
| | 9.6±0.50 | 0.36±0.019 |
| $^{nat}$Ni(α,γ) $^{65}$Zn | 1.08±0.38 | 0.32±0.065 |
| | 9.6±0.50 | 1.02±0.039 |
| $^{nat}$Ni(α,p) $^{61}$Cu | 1.08±0.38 | 0.009±0.00074 |
| | 9.6±0.50 | 2.52±0.21 |
| $^{nat}$Ti(α,n) $^{49}$Cr | 9.6±0.16 | 1.82± 0.27 |
| | 3.33±0.18 | 1.15± 0.18 |
| $^{nat}$Ti(α,γ) $^{51}$Cr | 9.6±0.16 | 69.27±12.64 |
| | 3.33±0.18 | 2.91± 0.15 |

## Conclusions

The $^{63,65}$Zn and$^{48}$V radionuclides were produced fromnatCu(p,x) andnatTi(p,x)reactions respectively, while$^{60}$Co,$^{60,61}$Cu,$^{57}$Ni radionuclideswere produced fromnatNi(p,x) reactions.Moreover the$^{66-68}$Ga,$^{65}$Zn,$^{60}$Co &$^{49,51}$Cr radionuclides were produced from$^{nat}$Cu(α,x) and$^{nat}$Tι(α,x) respectively & $^{62,63,65}$Zn,$^{61}$Cu radionuclides were produced from$^{nat}$Ni(α,x) reactions using foil activation technique.The production cross-sections of y$^{49}$Cr by$^{nat}$Tι(α,x) has been calculated at low energy for the first time.The cross-sections of$^{nat}$Ni(p,x)$^{57}$Ni,$^{nat}$Ni(p,x)$^{55}$Co,$^{nat}$Cu(p,x)$^{63}$Zn . natNi(p,x)57Ni reactions predicted by TALYS/TENDL differ the literature data. In some cases the theoretical calculations are either underestimated or overestimated in some energy regions. Therefore, parameters adjustment in model calculations is suggested.

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