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THERMAL NEUTRON ACTIVATION ANALYSIS OF SAUDI ARABIAN IRON ORES

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Abstract. Fe, Na, Sc, Cr, Co, Br, Sb, La, Sm, Tb, Lu, Th, and U in Saudi Arabian iron ores were determined using the instrumental neutron activation analysis. Gamma-ray activities, were measured by a Ge(Li) detector coupled with a 4096-channel pulse-height analyser. The amounts of Fe, Cr, and Sb were found to be Fe, 51.3±0.6%; Cr, 276±13 p.p.m. and Sb, 1.59±0.31 p.p.m.

Thermal neutron activation analysis is a technique[1–3] for determining qualitative and quantitative composition by means of nuclear transmutation and the subsequent measurement of emitted radiation from an unknown substance. This technique is widely used in determining trace elements present in various samples with high accuracy. Such studies are important since the characteristics of many materials are influenced by the existence of the trace element impurities. For example, the quality of steel is altered by its trace oxygen content;[4] the presence of trace vanadium in crude oil[5] poisons the platinum catalysts used in the cracking process by oil industry.[6] When a material is irradiated by thermal neutrons, some of its atoms interact with the bombarding neutrons and are converted into radioactive isotopes with known gamma-ray characteristics. The studies of the characteristic decay gamma-ray energies emitted by the activated sample and its half-lives can be used to identify the elemental composition of the sample. The intensity of the emitted radiation gives the concentration of the element in the sample. The identification of the various radioisotopes formed in the irradiated sample can be carried out by using gamma-ray spectrometer. The spectrometer used in this work consists of a high resolution Ge(Li) solid state gamma-ray detector coupled with a 4096-channel pulse height analyser. Samples of Saudi Arabian iron ore were analysed to determine the concentration of iron and to provide extra information about the trace elements present in the iron ore.

Experimental

A systematic technique of neutron activation of Saudi Arabian iron ore was carried out in the Institute for Radiochemistry, Garching, Technical University, Munich, Germany. This method worked properly since the trace elements present in the iron ore posses high thermal neutron cross-section and measurable half-lives with sufficient well resolved gamma-rays.

Irradiation. Samples of iron ore together with Sb, Cr and Fe_2O_3 standards were prepared in two vials. Sb (25.2 μg), Cr (20.0 μg) and Fe_2O_3 (containing 92.67 mg Fe) standards were contained in vial (1) together with two iron-ore samples of weights 84.7 and 32.8 mg. Similarly, vial (2) contained Sb (25.2 μg), Cr (20.0 μg), Fe_2O_3 (containing 80.29 mg Fe) standards and two iron-ore samples of weights 103.5 and 39.8 mg. All samples and standards in vial (2) were covered with cadmium sheet of 1 mm thickness. Both vials were irradiated in high neutron flux positions, near the core of the research reactor FRM, Munich. Neutron flux values of the two positions were 0.8×10^{13} n/cm² sec and 0.6×10^{13} n/cm² sec respectively. The corresponding times of irradiation were 16.15 and 24.17 hr. The irradiated vials were left for a period of about one week for cooling before starting activity measurements.

Activity Measurements. The radionuclides activity from the samples of the iron ore as well as the standard elements were counted using Ge(Li) detector, couples with a 4096-channel analyser (only 2000 channels were used). The energy scale was well-calibrated using gamma standard sources and the stability of the counting system was often checked using source. The linearity of the analyser was perfect with energy calibration of 1 keV per channel. The counting time was chosen to be 1 hr for each sample. Spectra obtained from all samples were examined visually and recorded digitally.

Results and Discussion

Qualitative analysis of energy spectra of the irradiated iron ore samples from vials 1 and 2 indicated the presence of elements Na, Sc, Cr, Co, Br, Sb, La, Sm, Tb, Lu, Th, and U beside the presence of Fe.

Figure 1 shows typical spectra obtained from an irradiated sample of iron ore of weight 39.8 mg covered with 1 mm thick cadmium sheet. The presence Fe^{59} isotope produce full energy peaks at 1099 and 1292 keV, and are clearly seen in spectra (1c) and (1d), while the other peaks at 143, 192 and 335 keV are visible in spectrum (1a). The full energy peak at 833 keV from the isotope Mn^{54} is clear in spectrum (1b). This isotope was formed through the reaction $Fe^{54}(n,p)$ $Mn.^{54}$ The full energy peak at 312 keV from the isotope Pa^{233} which was formed through the reaction Th^{232} (n,γ), $Th^{233} \xrightarrow{\beta^-} Pa^{233}$, indicates the presence of thorium in the iron ore. Similarly, full energy peaks at 228 and 277 keV in spectrum (1a) are due to Np^{239} resulting from the

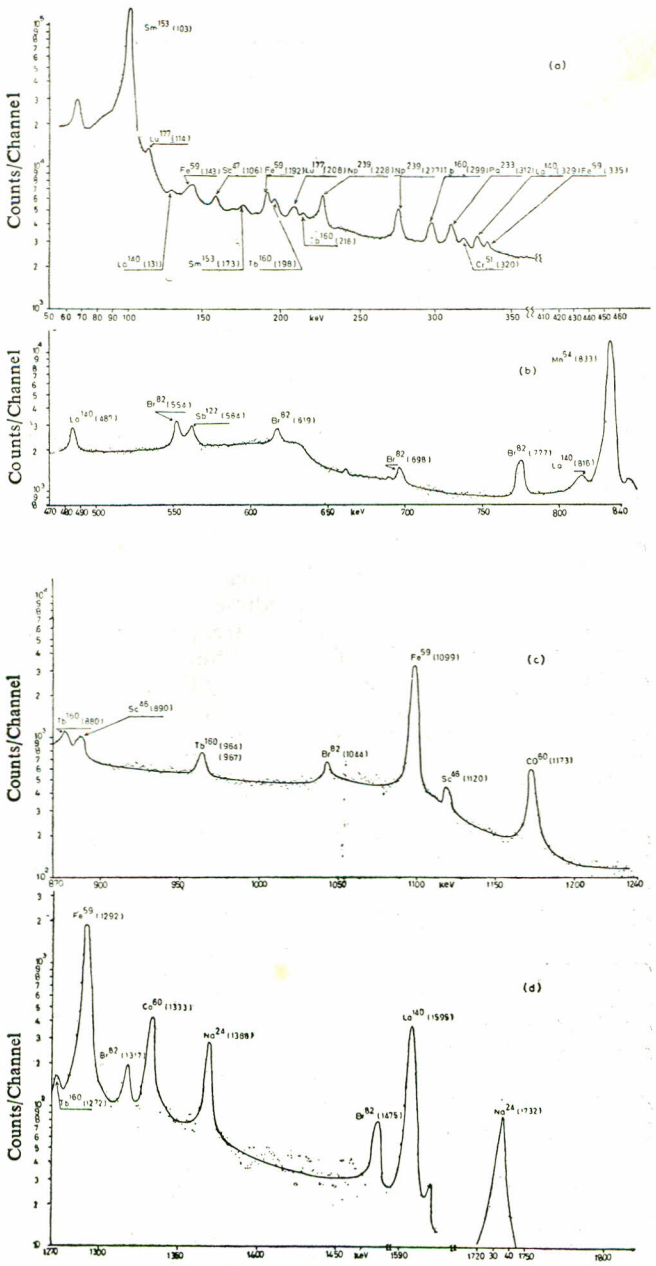

Fig. 1 (a,b,c and d). Gamma-ray spectra of irradiated Saudi Arabian iron ore sample. (Weight of sample, 39.8 mg; cooling time, 185.50 hr; time of irradiation, 24.17 hr; counting time, 1 hr; neutron flux$=0.6 \times 10^{13} \frac{n}{\text{cm}^2/\text{sec}}$

reaction $U^{238}(n,\gamma)\ U^{239} \xrightarrow{\beta^-} Np^{239}$ which implies the existence of uranium in the ore. Generally, the spectra contain many gamma-energy peaks some of them are clear and the others are visible depending on the half-lives as well as the reaction cross-section for each corresponding element.

The amounts of iron, chromium and antimony are determined quantitatively using the method described by Soltys and Morrison.[7] In this method the integrated area of each gamma-ray peak corresponding to each nuclide above the continuum was calculated from the digital data read out. Corrections for analyser dead time and for the decay time since irradiation to counting were considered. The amounts of Fe, Cr and Sb in the iron ore samples were determined by the comparison with the specific activity of their corresponding standards. The average amounts of Fe, Cr and Sb were found to be Fe, 51.3 $\pm$ 0.6%; Cr, 276 $\pm$ 13 p.p.m.; and Sb, 1.59 $\pm$ 0.31 p.p.m. It is clear that the analysis has provided extra information about other ten trace elements present in the Saudi Arabian iron ore. The amounts of these elements will be determined in another paper, using the data obtained in this work and applying the mono-standard activation analysis method described by Kim and Born.[8]

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