XX STUDENCKA SESJA PLAKATOWA

INSTYTUT FIZYKI
WYDZIAŁ FIZYKI, ASTRONOMII I INFORMATYKI STOSOWANEJ UJ

AUTOR:
JAVZMAA BATZUL

OPIEKUN:
DR TERESA JAWORSKA-GOŁĄB

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XRF investigation of mineral products of living creatures

Motivation

X-ray fluorescence (XRF) is an analytical method to determine the chemical composition of materials. This method is very fast, accurate and non-destructive, and requires only minimum of sample preparation [1].
Using the XRF method, the compositions of egg shells (araucana and chicken) and kidney calculus were identified.

Basic theory

What are X-rays?

X-rays are a form of electromagnetic radiation. The wavelength of X-rays are in range from 0,01 to 10 nm which corresponds to energies in the range from 0,125 to 125 keV [1].

Interaction of X-rays with matter

There are three main interactions when X-Rays contact matter: *Compton scattering (incoherent), Rayleigh scattering (coherent) and the photoelectric effect*. If a beam of X-ray photons is directed towards a slab of material some fraction will be transmitted through, a fraction is absorbed (producing flourescence radiation) and some fraction is scattered back [1].

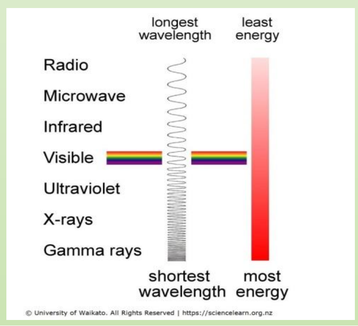

Fig1. X-Rays and other electromagnetic radiation [7]

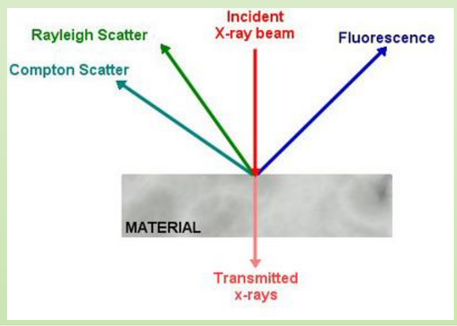

Fig2. The three main interactions of X-rays with matter [4]

Investigated mineral products of organisms

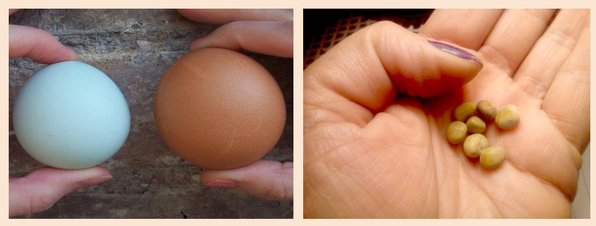

Fig3. Pictures of eggs (araucana egg (blue) and chicken egg) [5] and kidney calculus [6]

What is a mineral?
Minerals are solid, inorganic substances occuring in nature. They have a crystal structure and each mineral has a unique chemical composition. [3]

Experimental details

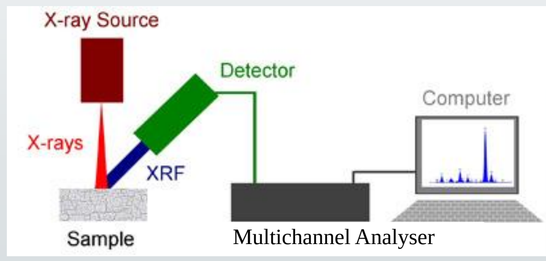

Fig4. Scheme of EDXRF spectrometer[2].

Energy dispersive X-ray fluorescence spectrometer MiniPal4 (PANalytical) used in the experiment was equipped with an X-ray tube with a Rh anode. The measurements were carried out in the air, without filters.

Interpretation of XRF spectra

- Emission lines from samples' elements (mainly K and L series), which are interested for a study

but also:

- Rayleigh peaks (elastic scattering)
- Compton peaks (inelastic scattering)
- Sum peaks (artificial peaks due to the arrival of two photons at the detector at exactly the same time [8])
- Escape peaks (artificial peaks due to the absorption of some of the energy of the secondary X-ray photons by Si atoms in the detector [8]; they are observed at the the energies lower by 1.74 keV)

Results

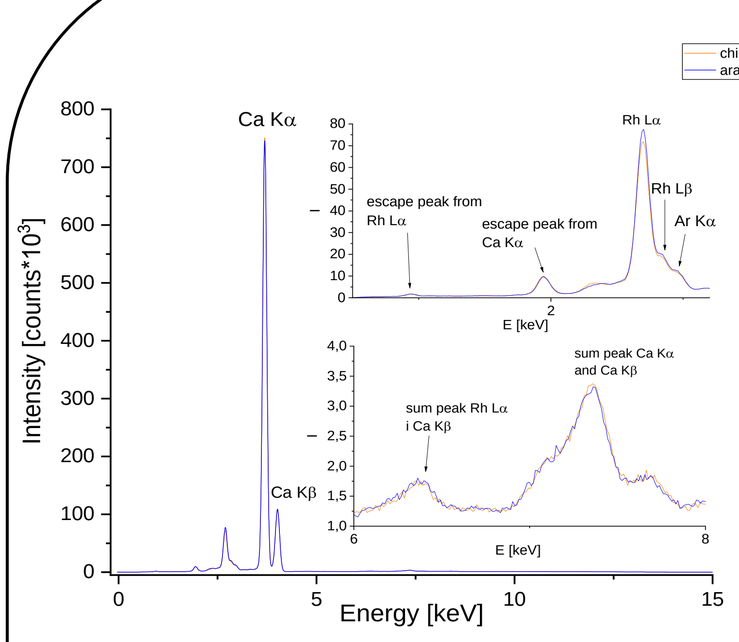

Fig5. XRF-spectra of eggs' shells

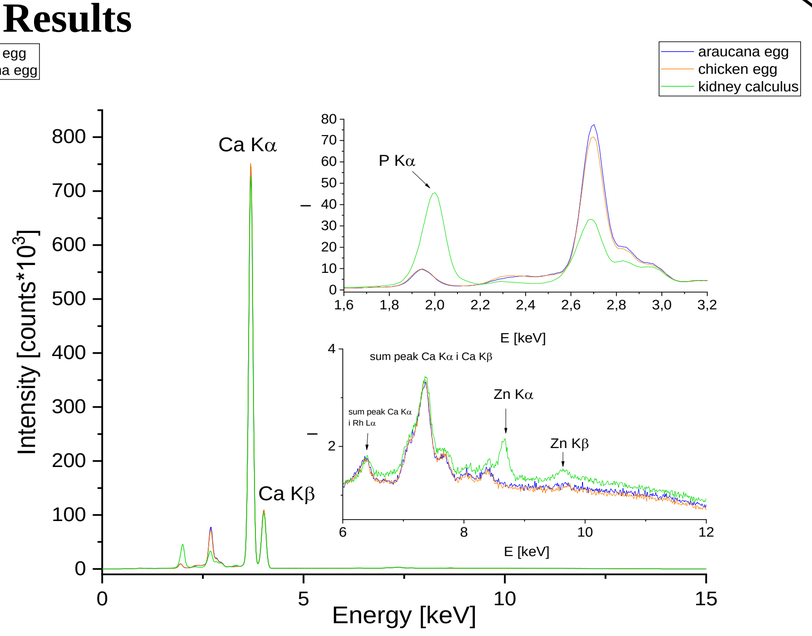

Fig6. XRF-spectra of all investigated minerals

Shells of araucana eggs and chicken eggs have shown very similar spectra. Both of them contain a lot of calcium. A difference is visible if we compare them with a kidney calculus's spectra. It contains a lot of calcium and some phosphorus and zinc. Intensities of all peaks of the kidney calculus are also different from the shells of the two eggs.

Table1. Energies of X-Ray emission lines

	Shell of the araucana egg [keV]	Shell of the chicken egg [keV]	Kidney calculus [keV]	E^{tab} [10] [keV]
Ca K_α	3,69 (± 6,2*10^{-5})	3,69 (± 6,04*10^{-5})	3,69 (± 4,8*10^{-5})	3,69
Ca K_β	4,01 (± 4,4*10^{-4})	4,01 (± 4,4*10^{-4})	4,01 (± 3,5*10^{-4})	4,01
Rh L_α	2,70 (± 7,3*10^{-4})	2,70 (± 7,8*10^{-4})	2,71 (± 2,3*10^{-3})	2,69
Rh L_β	2,84	2,83	2,83	2,83
P K_α	-	-	1,99 (± 8,7*10^{-4})	2,01
Ar K_α	2,95	2,95	2,95	2,95

Conclusions

With the use of X-ray fluorescence, qualitative analysis of chemical composition of selected mineral products of living creatures was performed. In the collected XRF spectra (Fig.5 and Fig.6) there are visible emission lines of rhodium (Rh) because the spectrometer was equipped with an X-ray tube with a Rh anode and also there are emission lines of argon (Ar) because the measurements were carried out in the air (Ar content ca. 9340 ppm [9]).

XRF spectra of araucana and chicken egg shells are very similar even if we can differ the samples by eye. The reason is as follows: colors of birds eggs' shells come from porphyrins, which are pigments consisting of C, N, O, H i.e. the elements not detectable in our experiment.

The main component of all the samples is calcium (Ca). There are Ca K_α, Ca K_β as well as the sum and escape peaks well visible in the XRF spectra. The studied kidney stone contains also some amount of phosphorus (P) and zinc (Zn). A quantitative analysis of the samples' composition was not the task of this study.

Experimental energies of all detected peaks are very close to the literature values (Table 1; the errors come from refinements of the line profiles by Gaussian curve-fitting).

Acknowledgements

Availability of XRF spectra of a kidney stone from the II PF Data Base is gratefully acknowledged.

References

[1] Theory of XRF, T. Brouwer
[2] *http://physicsopenlab.org/2016/02/24/diy-xrf-spectrometry/ ;* on-line May 2018.
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[6]*https://commons.wikimedia.org/wiki/File:Kidney_stones_(_renal_calculi_),_%D0%91%D1%83%D0%B1%D1%80%D0%B5%D0%B6%D0%BD%D0%B8_%D0%BA%D0%B0%D0%BC%D0%B5%D1%9A%D0%B0_4.jpg ;* on-line May 2018.
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