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Use of Ionising Radiation in the Teaching of Physics and Chemistry

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RADIATION AND NUCLEAR SAFETY AUTHORITY

STUK

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Use of Ionising Radiation in the Teaching of Physics and Chemistry

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RADIATION AND NUCLEAR SAFETY AUTHORITY

Authorisation

Under section 70, paragraph 2, of the Radiation Act (592/1991), STUK – Radiation and Nuclear Safety Authority (Finland) issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation.

The Radiation Act stipulates that the party running a radiation practice is responsible for the safety of the operations. The responsible party is obliged to ensure that the level of safety specified in the ST Guides is attained and maintained.

Translation. Original text in Finnish.

1 General

Appliances producing ionising radiation for use in school education are usually of low power, and the amount of radioactive material used as the radiation source is small. Nevertheless, it is highly important to act with caution and to follow the operating instructions during demonstrations and practical exercises in order to avoid radiation exposure to the pupils and teacher. Other important aspects in ensuring radiation safety include the good quality and condition of the appliances, as well as strict adherence to the regulations concerning the storage and disposal of radioactive materials. It is also important that the radiation meters used in teaching are sufficiently sensitive to register even the slightest amount of radiation.

This guide lays down the safety requirements for the use of radiation in school education, as well as the principles regulating the use of radiation sources without the safety licence referred to in section 16 of the Radiation Act (592/1991). The guide covers the use of radiation sources emitting ionising radiation in elementary schools and high schools, as well as the use of radiation in the teaching of physics and chemistry in vocational training institutions and corresponding educational institutions.

2 Licensing of Radiation Use

According to section 16 of the Radiation Act (592/1991), the use of radiation is generally not permitted without a safety licence. Exemption from the safety licence and grounds for such exemption are specified in section 17 of the Radiation Act, which states that the Radiation and Nuclear Safety Authority (STUK) may exempt a specific use of radiation from the safety licence, if it can be ensured to a sufficiently reliable degree that such a use of radiation does not constitute a health hazard or other danger. The basic criteria for exemption values and for the exemption of the use of radiation from the safety licence and reporting obligation are presented in ST Guide 1.5.

2.1 Use of Radiation Exempted from the Safety Licence

2.1.1 Radiation Appliances Approved for Educational Use

In decision No. 1092/310/1992, STUK has exempted the use of teaching aids—which produce ionising radiation electrically and which contain sealed sources—from the safety licence, when the use of such radiation is related to the teaching of physics or chemistry in schools, vocational training institutions or corresponding educational institutions. The exemption decision sets the following requirements as the condition for granting exemption from the safety licence:

- The radiation appliance shall be approved for educational use. A radiation appliance is approved for educational use if it has been inspected by STUK, or inspected and approved elsewhere as presupposed in an international treaty ratified by Finland.
- The school shall notify STUK within one month after the acquisition of a radiation appliance.
- The total activity of the radionuclides emitting alpha radiation in the radiation appliances possessed by the school shall not exceed 370 kBq.
- The school shall designate a person responsible for radiation safety whose task is to supervise that radiation protection regulations and instructions are followed in the use and storage of radiation sources and in the disposal of radioactive waste.
- Any radiation sources containing radioactive material which are broken or no longer in use must be treated as radioactive waste. If necessary, STUK shall be contacted for instructions concerning the disposal of the waste, unless the waste can be returned to the importer of the appliance.

The importer or manufacturer of the appliance is responsible for applying for the inspection referred to in the exemption decision. If there is no mark of inspection or approval on the appliance or in the enclosed documents, STUK must be contacted for further information about the licence and inspection requirements related to

the use of the appliance. Any radiation appliances which STUK has earlier approved in radiation use inspections in schools and educational facilities can still be used without the safety licence, providing that the special conditions stipulated in the inspection documents and the restrictions on use, specified here in chapter 4, are observed.

2.1.2 Radiation Appliances in the Form of Consumer Goods. Exemption Values

The following uses of radiation have been exempted from the safety licence directly on the basis of the Radiation Act, or by separate decisions of STUK:

- The use of radiation appliances in the form of consumer goods. Such appliances include smoke detectors for domestic use and compasses containing radioluminous paint.
- The use of a radiation appliance which, due to the very small radiation exposure caused by it, has been exempted from control. Such appliances include appliances containing a sealed source in which the activity does not exceed the exemption value.
- The use of a radioactive material when the activity possessed at one time is less than the exemption value, or the activity concentration does not exceed the exemption value.

In the case of a mixture of radionuclides or more than one radionuclide, a safety licence will not be needed for the use of radiation, if the following condition is met:

$$\sum_k \frac{A_k}{A_{E,k}} \le 1 \quad or \quad \sum_k \frac{C_k}{C_{E,k}} \le 1 .$$

Where:

A_k is the activity of radionuclide k,
$A_{E,k}$ is the exemption value for radionuclide k,
C_k is the activity concentration of radionuclide k, and
$C_{E,k}$ is the exemption value for radionuclide k.

The exemption values are presented in ST Guide 1.5. The exemption values apply in the same manner to both unsealed and sealed sources. The exemption values of the most commonly used radionuclides are as follows:

Radionuclide	Activity (kBq)	Activity-concentration (kBq/kg)
Co-60	100	10
Sr-90	10	100
Cs-137	10	10
Ra-226	10	10
Am-241	10	1

If the radiation appliances used as teaching aids are classified as consumer goods or exempted from control as specified above, it is not necessary to notify STUK about them. The licence or notification procedure is not applicable to radioactive mineral or rock samples which schools may possess for teaching purposes.

The use of unsealed sources—such as radioactive material in the form of a solution or powder—which are below the exemption values is also exempted from the safety licence. Instead of applying for a safety licence, the school shall notify STUK about the use of such unsealed sources. If radionuclide generators, such as $^{90}Sr/^{90}Y$ and $^{137}Cs/^{137m}Ba$, are used for generating unsealed sources, they shall be approved for teaching purposes according to item 2.1.1, even though the exemption values are not exceeded. However, it is advisable to avoid using radioactive materials as unsealed sources unless such use is educationally essential.

If the electrical apparatus has no parts which operate at a voltage greater than 5000 V, the provisions concerning ionising radiation shall not apply to the use of the apparatus, even though the apparatus does in fact produce ionising radiation.

2.2 Licenced Use of Radiation

If radiation sources other than those exempted from the safety licence as per item 2.1 are used for teaching purposes, the school shall apply to STUK for a safety licence. The application procedure for a safety licence is stipulated in the Radiation Decree (1512/1991). Depending on the nature and extent of the use of radiation, the safety licence application shall contain sufficient information about such items as the locality where the radiation is used, radiation sources, protective and safety systems used, arrangements for the monitoring of radiation exposure, as well as the handling of radioactive waste and rendering it harmless. Furthermore, a person who has completed an appropriate radiation protection course, or proved his/her competence in a separate radiation protection hearing, shall be designated as the radiation safety officer responsible for the safe use of radiation. Application forms and additional information about applying for a safety licence, or an exemption from the safety licence on the basis of section 17 of the Radiation Act (592/1991), are available from STUK.

It is recommendable to arrange the use of radiation in high-school or elementary-school education in a manner not requiring a safety licence.

3 Safety Requirements

3.1 Limiting of Radiation Exposure

According to the general principles of radiation protection, exposure to radiation must be kept as low as is reasonably achievable. The use of radiation at schools shall be planned and arranged in such a way that the effective dose caused by it to the teaching staff, pupils and other persons during one year does not exceed 1 mSv. According to Publication No. 36 of the International Commission on Radiological Protection (ICRP), the recommended annual dose limit for pupils is 0.5 mSv. The dose caused by one demonstration to a pupil shall not exceed 0.05 mSv.

3.2 Responsible Person

It is not necessary to have a safety licence for the use of radiation referred to in item 2.1, but the school must designate a person responsible for radiation safety. It is preferable that the responsible person be one of the physics or chemistry teachers. The responsible person shall familiarise him/herself with the radiation safety regulations and instructions related to the use of teaching aids. The person shall also ensure that the radiation sources are in good condition as regards radiation protection, and that there are operating and safety instructions and special regulations—which are designated as mandatory in the inspection documents of the radiation sources or other documentation—readily available to the teachers for their demonstrations. A summarised list of the most essential instructions and radiation safety aspects should be drawn up and placed in the laboratory or the room where the radiation sources are stored. An example of such a summary can be found in Appendix A.

3.3 Marking and Storage of Radiation Sources

The radiation appliances shall be furnished with a sign warning about ionising radiation. The radiation sources containing radioactive material shall also be furnished with a marking indicating the radionuclide in question, its activity and the date at which the activity was determined.

The radiation sources shall be returned to their storage place immediately after the lesson. The storage place shall be lockable, and access to or opening of such a storage space be permissible only with the consent of the teacher or person responsible for radiation safety. The storeroom or storage cupboard in which radioactive materials are stored must be furnished with a warning sign indicating a danger of ionising radiation. A list must be kept of the radiation sources, indicating the identification data of the radiation source, such as the manufacturer,

type, serial number, radionuclide, its activity, and the date at which the activity was determined.

When a radioactive material is removed as waste, the list must be furnished with a marking indicating the date and the place to where the waste has been delivered.

3.4 Protection Instructions

The teacher must make sure that the radiation sources are not used longer than is educationally necessary, and that the pupils do not handle the radiation sources needlessly or without supervision.

The area directly in front of the primary beam of an X-ray appliance shall be kept free of persons. The safety distance in other directions is usually 1.5 m.

The decrease in radiation intensity is directly proportional to the square of the distance from the radiation source. Radiation exposure can, thus, be easily reduced by increasing the distance from the radiation source.

An example.
The dose rate of gamma radiation emitted by an unsealed point source containing 370 kBq of ^{137}Cs is 3.3 μSv/h at a distance of 10 cm from the source but, according to the square rule, only 0.033 μSv/h at a distance of one metre.

A radiation source containing radioactive material shall not be kept outside its radiation shield for longer than is necessary. A radiation source removed from its shield shall be handled in such a way that no part of the body is needlessly exposed to the radiation.

4 Restrictions on Use

It is not allowed to use unshielded X-ray appliances in school education.

Cold cathode type discharge tubes may generate X-rays. Such X-rays are not dangerous if the voltage in the discharge tube does not exceed 5000 V. Therefore, an adjustable voltage source with a maximum voltage of more than 5000 V shall not be used in connection with a discharge tube without a voltmeter or some other means of ensuring that the voltage does not exceed 5000 V. A spark inductor may not be used as a voltage source for appliances generating X-rays.

The above-mentioned discharge tubes include the following:

- a so-called Crookes tube demonstrating the bending of cathode rays in a magnetic field
- a Braun tube
- cathode-ray tubes containing fluorescent material
- a shadow cross tube
- a tube for demonstrating the pressure of cathode rays
- a tube for demonstrating the thermal effect of a cathode ray
- a canal ray tube.

^{226}Ra sources which have been in use for more than 10 years shall not be used prior to ensuring their tightness. A leakage test in accordance with section 7 of standard SFS 5111 shall be carried out once a year or prior to starting the demonstration at the latest. If a leak is found in a sealed source, use of the source must be terminated and it shall be treated as radioactive waste.

5 Bibliography

1 ICRP Publication 36, Protection against Ionising Radiation in the Teaching of Science. The International Commission on Radiological Protection, Pergamon Press, Oxford 1983.

2 SFS 5111, Sealed radioactive sources. Leak test methods during use. (in Finnish)

APPENDIX A

RADIATION SAFETY WHEN USING DEMONSTRATION AIDS

1. Make sure that the radiation sources are not damaged and that their safety mechanisms function properly.

2. Follow the operating instructions for the appliance in question.

3. Use radiation sources only for as long as is educationally necessary.

4. During the demonstration, make sure that nobody is directly in front of the primary beam of an X-ray appliance, and that the pupils do not handle the radiation sources needlessly or without supervision.

5. Do not keep a radiation source containing radioactive material needlessly outside its shield. Always handle an unshielded radiation source in such a way as to ensure that no part of the body is needlessly exposed to the radiation.

6. Return the radiation sources to their storage place immediately after the demonstration.

7. Damaged or misplaced radiation sources must be reported to the person responsible for the radiation safety.

8. For more information about the use of radiation, contact STUK – Radiation and Nuclear Safety Authority, telephone (09) 759 881.

THE PERSON RESPONSIBLE FOR RADIATION SAFETY AT THIS SCHOOL IS:

_____

APPENDIX B

DEFINITIONS

Activity refers to the number of spontaneous nuclear transformations in a given amount of radionuclides or material during a given period of time divided by this period of time. The unit of activity is becquerel (Bq). An activity of one becquerel is possessed by the amount of material in which, on the average, one nuclear transformation occurs per second.

Effective dose refers to the weighted sum of the equivalent doses of tissues and organs exposed to radiation. The unit of effective dose is sievert (Sv). 1 Sv = 1 $J \cdot kg^{-1}$.

Equivalent dose refers to a dose which is obtained by dividing the average energy absorbed from the radiation in the tissue or organ by the mass of the tissue or organ, and multiplying the quotient by the weighting factor of the radiation. The unit of equivalent dose is sievert (Sv).

Ionising radiation refers to radiation that produces ions in the medium. Ionising radiation includes gamma, X-ray, alpha and beta radiation, as well as electrons, neutrons, protons and other nucleons.

Radiation appliance refers to an appliance that produces radiation by electricity or contains radioactive material.

Radiation source refers to a radiation appliance or radioactive material.

Radiation use refers to the use and production of, and trade in radiation sources as well as the related functions, such as possession, holding, servicing, repairing, installation, importation, exportation, storage, transportation, and rendering radioactive material harmless.

Radioactive material refers to material that contains one or more radionuclides.

Radioactive waste refers to radioactive materials, and equipment, goods and materials contaminated by radioactive materials, that have no use and must be rendered harmless owing to their radioactivity.

Radionuclide refers to a nuclide that decays by itself and emits ionising radiation.

Sealed source refers to a radiation source in which the radioactive material is encapsulated or covered in such a way as to ensure that the material cannot be touched or that it does not spread out in the conditions in which it is intended to be used.

Unsealed source refers to a radiation source in which the radioactive material is not shielded by a tight casing.