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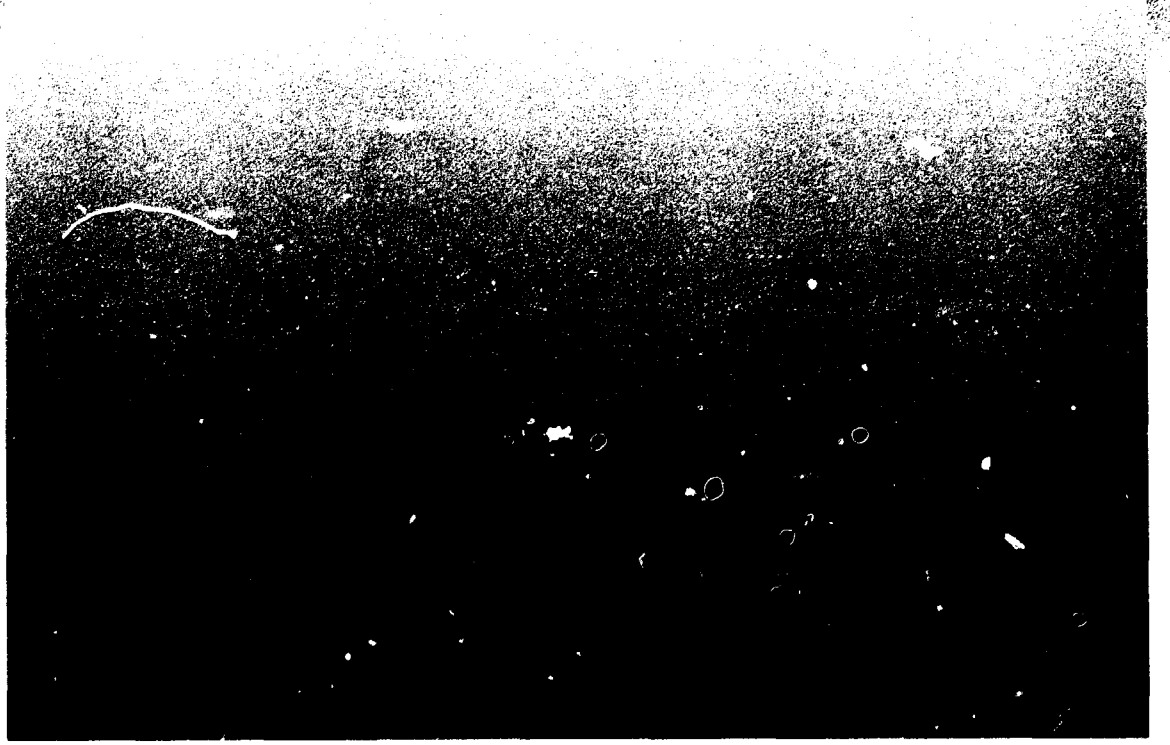
Use of ionizing radiation in the teaching of physics and chemistry



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FINNISH CENTRE FOR RADIATION
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Use of ionizing radiation in the teaching of physics and chemistry

This ST Guide takes effect on 1 February 1993 and will remain in force until further notice. It replaces SS Guide 5.3, "Use of ionizing radiation in the teaching of physics and chemistry", issued on 10 April 1987.

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Authorization

Under section 70, paragraph 2, of the Radiation Act (592/91), the Finnish Centre for Radiation and Nuclear Safety 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.

The instructions given in the ST Guides on actions and procedures are not absolutely binding, but if the responsible party intends to use a procedure or method differing from those presented in an ST Guide, he must be able to prove that the procedure or method chosen ensures the same level of safety as that specified in the ST Guide.

Radiation Protection Guides (SS Guides) issued before 1992 and listed at the end of this guide remain in force until further notice. SS Guides will be replaced by ST Guides whenever the need arises to alter their contents.

Translation. Original text in Finnish.

1 General

Appliances producing ionizing radiation used in school education are usually of low power and the amount of radioactive material used as the source of radiation is small. Nevertheless, it is highly important to act with caution and follow the operating instructions during demonstrations and practical excercises in order to avoid radiation exposure of the pupils and teacher. Other important aspects in ensuring radiation safety include the good quality and condition of the appliances, as well as the strict observation of the regulations concerning the storage and disposal of radioactive materials. It is also important that the radiation meters used in teaching are modern and sufficiently sensitive to register even the slightest 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 license referred to in Section 16 of the Radiation Act (592/91). The guide covers the use of radiation sources emitting ionizing 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 (592/91), the use of radiation is generally not permitted without a safety license. Exemption from the safety license and grounds for such exemption are specified in Section 17 of the Radiation Act, which states that the Finnish Centre for Radiation and Nuclear Safety may exempt a certain use of radiation from the safety license, 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.

2.1 Use of radiation exempted from the safety license

2.1.1 Radiation appliances approved for educational use

In decision No. 1092/310/92, the Finnish Centre for Radiation and Nuclear Safety has exempted the use of teaching aids – which produce ionizing radiation electrically and which contain sealed sources – from the safety license, when the use of such radiation is related to the teaching of physics or chemistry in schools, vocational training institutions or corresponding institutions. The above-mentioned decision also supercedes the earlier decision, No. 1659/320/86, concerning the exemption of teaching aids from the safety license. The exemption decision sets the following requirements as the condition for granting exemption from the safety license:

- The radiation appliance shall be approved for educational use. A radiation appliance is approved for educational use, if it has been inspected by the Finnish Centre for Radiation and Nuclear Safety, or inspected and approved elsewhere as presupposed in an international treaty ratified by Finland.

- The school shall notify the Finnish Centre for Radiation and Nuclear Safety within one month after the acquisition of a radiation appliance, if so stipulated in the inspection documents of the 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, the Finnish Centre for Radiation and Nuclear Safety 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, the Finnish Centre for Radiation and Nuclear Safety must be contacted for further information about the license and inspection requirements related to the use of the appliance. Any radiation appliances which the Finnish Centre for Radiation and Nuclear Safety has earlier approved in radiation use inspections in schools and educational facilities can still be used without the safety license, providing that the special conditions stipulated in the inspection documents and the restrictions on use specified here in Section 4 are observed.

2.1.2 Radiation appliances in the form of consumer goods. Exemption limits

The following uses of radiation have been exempted from the safety license directly on the basis of the Radiation Act or by separate decisions of the Finnish Centre for Radiation and Nuclear Safety:

- 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 machines emitting X-rays when the energy of the radiation does not exceed 5 keV, and appliances containing a sealed source in which the activity does not exceed the exemption limit.

- The use of a radioactive material when the activity possessed at one time is less than the exemption limit, and the total activity acquired during one year is not more than ten times the exemption limit.

- The use of a radioactive material when the activity of the material is less than 100 Bq in one gram.

The exemption limits for radionuclides are presented in ST Guide 1.5. The exemption limits of the most commonly used radionuclides are as follows:

^{241}Am and ^{226}Ra	5 kBq
^{60}Co and ^{90}Sr	50 kBq
^{137}Cs	500 kBq

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 the Finnish Centre for Radiation and Nuclear Safety about them. The license or notification procedure is not applicable to radioactive mineral or rock samples which schools may possess for teaching purposes either.

The use of unsealed sources – such as radioactive material in the form of a solution or powder – which are below the exemption limits is also exempted from the safety license. Instead of applying for a safety license, the school shall notify the Finnish Centre for Radiation and Nuclear Safety about the use of the 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 section 2.1.1, even if the exemption limits are not exceeded. However, it is advisable to avoid using radioactive materials as unsealed sources, unless such use is educationally essential.

2.2 Licensed use of radiation

If radiation sources other than those exempted from the safety license as per section 2.1 are used in the teaching, the school shall apply to the Finnish Centre for Radiation and Nuclear Safety for a safety license. The application procedured for a safety license is stipulated in the Radiation Decree (1512/91). Depending on the nature and extent of the use of radiation, the safety license application shall contain sufficient information about such items as the locality where the radiation is used, radiation sources, protective and safety systems used, arranging for the monitoring of radiation exposure, as well as the handling of the 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 a person responsible for the use of radiation. Application forms and additional information about applying for a safety license, or an exemption from the safety license on the basis of Section 17 of the Radiation Act (592/91), are available from the Finnish Centre for Radiation and Nuclear Safety.

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

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 so 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 license for the use of radiation referred to in section 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 familiarize 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 a good condition as regards radiation protection, and that there are operating and safety instructions and special regulations - which are made mandatory in the inspection documents of the radiation sources or other documentation - readily available to the teachers for their demonstrations. A summarized 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 App. A.

3.3 Marking and storage of radiation sources

The radiation appliances shall be furnished with a sign warning about ionizing radiation. The radiation sources containing radioactive material shall also be furnished with a marking indicating the radionuclide in question, 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 is 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 danger of ionizing radiation. A list must be kept of the radiation sources, indicating the identification data of the radiation source, such as the manu-

facturer, type, serial number, radionuclide, 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 when and where the material was removed and 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. 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 so that no part of the body is needlessly exposed to the radiation.

4 Restrictions to 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 5 000 V. Therefore, an adjustable voltage source with a maximum voltage of more than 5 000 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 5 000 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, and
- 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 noticed in a sealed source, the use of such source must be terminated and it shall be treated as radioactive waste.

5 Bibliography

1 ICRP Publication 36, Protection against Ionizing 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).

3 Radiation and Safety. Toivonen, H.,Rytömaa, T. and Vuorinen, A. (editor). State Printing Office, 1988 (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 the Department of Radiation Safety of the Finnish Centre for Radiation and Nuclear Safety (phone 90-70821).

THE PERSON RESPONSIBLE FOR RADIATION SAFETY AT THIS SCHOOL IS:

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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 one nuclear transformation occurs per second on average.

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

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/kg.

Equivalent dose refers to a dose which is obtained by dividing the average energy absorbed from the radiation to 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). 1 Sv = 1 J/kg.

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

Radioactive material refers to material which 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 which decays by itself and emits ionizing radiation.

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, keeping, servicing, repairing, installation, importation, exportation, storage, transportation, and rendering radioactive material harmless.

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

FINNISH CENTRE FOR RADIATION
AND NUCLEAR SAFETY
1.8.1993

ST(SS) GUIDES

General Guides

ST 1.2 Application of maximum radiation exposure values and monitoring of radiation exposure, 31 March 1992 (in English, Finnish and Swedish)
ST 1.3 Safety signs denoting radiation sources, 9 April 1992 (in Finnish and Swedish)
ST 1.4 Organization for the use of radiation, 24 October 1991 (in Finnish and Swedish)
ST 1.5 Maximum values and classification of radionuclides, 26 November 1991 (in English, Finnish and Swedish)
ST 1.6 Monitoring of radiation exposure and registration of doses, 16 December 1992 (in English, Finnish and Swedish)
ST 1.7 Health surveillance of persons engaged in radiation work, 19 December 1991 (in English, Finnish and Swedish)

Radiation Therapy

ST 2.1 Quality assurance of radiotherapy equipment, 13 January 1993 (in Finnish)
SS 2.8 Radiation protection requirements for radiotherapy equipment and rooms. High-energy radiotherapy equipment, 21 December 1989 (in English, Finnish and Swedish)
SS 2.9 Radiation protection requirements for radiotherapy equipment and rooms. X-ray therapy equipment (25 kV ... 400 kV), 21 December 1989 (in Finnish and Swedish)
SS 2.10 Radiation protection requirements for radiotherapy equipment and rooms. Afterloading therapy equipment, 21 December 1989 (in Finnish and Swedish)

Diagnostic Radiology

SS 3.1 Dental X-ray equipment: type inspection and technical requirements, 25 February 1987 (in English, Finnish and Swedish)
SS 3.2 Radiation safety requirements for mammographic equipment, 17 February 1987 (in English, Finnish and Swedish)
ST 3.3 Diagnostic X-ray equipment and its use, 27 August 1992 (in English, Finnish and Swedish)
ST 3.4 Quality control of X-ray image-intensifier television chains, 24 October 1991 (in Finnish and Swedish)
ST 3.5 Quality control of diagnostic X-ray equipment and film processing, 3 December 1991 (in Finnish and Swedish)
ST 3.6 Radiation shielding of X-ray examination rooms, 20 December 1991 (in English, Finnish and Swedish)

Measurement of Radiation

ST 4.2 Radiation meters for civil defence, 6 June 1991 (in English and Finnish)

Industry, Research, Education and Commerce

ST 5.1 Radiation safety of sealed sources and equipment containing them, 27 August 1992 (in English, Finnish and Swedish)
ST 5.3 Use of ionizing radiation in the teaching of physics and chemistry, 14 December 1992 (in English, Finnish and Swedish)
SS 5.4 Import and export of and trade with radioactive materials and equipment containing them, 9 January 1989 (in English, Finnish and Swedish)
SS 5.6 Radiation safety in industrial radiography, 6 January 1989 (in English, Finnish and Swedish)
SS 5.8 Installation, repair and maintenance of radiological equipment used for medical purposes, 28 March 1988 (in English, Finnish and Swedish)
SS 5.9 Transport of radioactive materials, 16 May 1989 (in Finnish)

Unsealed Sources and Radioactive Wastes

ST 6.1 Radiation safety requirements for radionuclide laboratories, 30 May 1991 (in English, Finnish and Swedish)
ST 6.2 Radioactive wastes and discharges, 20 December 1991 (in English, Finnish and Swedish)

Non-Ionizing Radiation

SS 9.1 Radiation safety requirements and type inspection of solarium equipment and sun lamps, 1 September 1989 (in Finnish and Swedish)

ST 9.2 Radiation safety of pulsed radars, 11 December 1991 (in Finnish)

ST 9.3 Radiation safety during work on masts at FM and TV stations, 9 April 1992 (in Finnish)

Natural Radiation

ST 12.1 Radiation safety in mining and underground excavation, 27 August 1992 (in Finnish and Swedish)

ST 12.2 Radioactivity of building materials, fuel peat and peat ash, 2 February 1993 (in Finnish)

SS Guides will be converted into ST Guides wherever necessary.