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Radiation Safety

Radiation Safety Handbook for Using:

Radioactive Materials

Sources of Radioactive Radiation

Devices Emitting Ionizing Radiation

Radiation Safety Handbook

Written by Rafi Srebro

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Introduction

This handbook contains explanations and radiation safety procedures for using radioactive materials, radiation sources, and radiation-emitting devices. The aim of the procedures is to permit safe working and to protect the health of personnel. The procedures apply to all university personnel: academic staff, technical and administrative staff, and students using radioactive radiation.

Please read the procedures with care and attention; then fill in the required information on the form at the back of the handbook and return it to the Radiation Safety Unit. Keep the handbook with you – its contents can help you in your work.

REMEMBER!

STARTING WORK WITH RADIOACTIVE MATERIAL, SOURCES OF RADIATION, OR RADIATION EMITTING DEVICES, WITHOUT AUTHORIZATION FROM THE RADIATION SAFETY UNIT, IS PROHIBITED.

YOU CAN FIND THE HEBREW VERSION OF THIS MANUAL AND MORE INFORMATION ON RADIATION PROTECTION IN OUR INTERNET SITE : WWW.BGU.AC.IL/RADIATION .

REMEMBER: YOUR SAFETY IS MY CONCERN BUT IT IS YOUR RESPONSIBILITY !!!!

PREPARING FOR WORK WITH RADIOACTIVE RADIATION AT BEN-GURION UNIVERSITY

1. **READ THE RADIATION SAFETY HANDBOOK; FILL OUT THE FORM ON THE LAST PAGE AND SEND IT TO THE RADIATION SAFETY OFFICE.**
2. **ATTEND RADIATION SAFETY LECTURE.**
3. **LEARN HOW TO WORK SAFELY WITH RADIATION IN THE LABORATORY.**
4. **PLAN YOUR STUDIES AND PRACTICE THE PROCEDURES IN ADVANCE.**
5. **GET YOUR REQUIRED MEDICAL CHECKUP.**
6. **OBTAIN PERMISSION FROM RADIATION SAFETY AND FROM THE HEAD OF THE LABS IN ADVANCE OF CARRYING OUT YOUR EXPERIMENT.**

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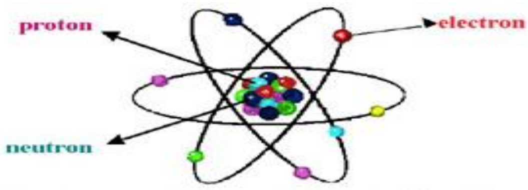
<u>**General Background**</u>

Radioactivity is defined as spontaneous nuclear change as a result of which a new nucleus or element is formed. The change is accompanied by the emission of particles and/or electromagnetic radiation. Radioactivity is a characteristic of unstable isotopes (atoms of the same element but with differing numbers of neutrons in their nuclei) that 'choose' to enter a more stable state by a process of radioactive decay, also known as disintegration.



The various elements are distinguished by the number of radioactive isotopes they possess. Thus, for example, hydrogen has 3 isotopes in all, of which only one is radioactive, while lead has 32 isotopes, of which just 3 are non-radioactive (stable). Below is a table of the isotopes of hydrogen.

Sign of isotope	Name of isotope	Number of protons	Number of neutrons	Atomic weight	Stable isotope	Radioactive isotope
H^1	hydrogen	1	0	1	x	
H^2	deuterium	1	1	2	x	
H^3	tritium	1	2	3		x

The particles and the electromagnetic radiation that are emitted as a result of radioactive decay are called radioactive radiation.

Radioactive radiation is characterised by its ability to cause ionisation (emission of an electron from the atom) when it traverses any medium.

Ionisation is the process by which the radiation loses energy, and is also the process responsible for the damage caused by radioactive radiation.

Radioactivity is not a new phenomenon. The planet Earth, from the moment of its creation, has been continuously exposed to radioactive radiation from a variety of sources: cosmic radiation, radiation caused by the decay of radioactive isotopes (such as uranium) in the ground and in the oceans, and even from radioactive isotopes occurring naturally in our own bodies (such as an isotope of potassium).

<u>Types of Radiation</u>

In the process of radioactive decay, various forms of radioactive radiation occur, the main types of which are detailed below:

<u>Alpha Radiation</u> (α):

Radiation of particles that are actually nuclei of the ionised element He (2 protons and 2 neutrons, without electrons); the particles have a positive electrical charge. Alpha radiation has a range of a few centimetres through the air and is halted by any denser agent (a sheet of paper one millimetre thick is sufficient to stop it). The short range is caused by a very high degree of ionisation, so that the radiation loses its energy over a very short distance.

$$^{226}_{88}Ra \xrightarrow{\alpha} {}^{222}_{86}Rn + {}^{4}_{2}He^{++}$$

Beta Radiation (**β–**):

Radiation of charged particles, electrons or positrons (distinguishing between β+ and β- respectively. Beta radiation has a range through the air of up to several meters and requires a thickness of several millimetres of water or aluminium, or some 10-12 millimetres of Perspex, to stop it. Most of the materials used in biological and medical research emit beta radiation.

$$^{32}_{15}P \xrightarrow{\beta} {}^{32}_{16}S + {}^{0}_{-1}\beta + \nu$$

In medical diagnostics we use materials that emit β+(positive electrons).Because beta+ radiation will always be accompany with gamma radiation.

$$^{18}_{9}F \xrightarrow{\beta} {}^{18}_{8}O + {}^{0}_{+1}\beta + \nu + \gamma$$

Gamma Radiation (γ):

Electromagnetic radiation lacking both mass and electrical charge. In the air it has a range of tens of meters, and can penetrate several centimetres of a heavy material such as lead. Another form of radiation known as X radiation (commonly called X rays) is also known to us. It has properties identical to those of Gamma radiation. The difference in names has mainly historical reasons. In most cases of recourse to electromagnetic radiation in medical diagnosis and treatment, X rays or Gamma radiation are used.

We know of other forms of radioactive radiation, such as neutron radiation (n) and proton radiation (p). They are used for research in physics and atomic engineering.

Kinetics of Radioactive Decay

Radioactive decay is a statistical phenomenon. We can know how many nuclei disintegrate per unit of time, but not which nuclei will do so.

If we call the number of radioactive nuclei existing for a given time N , and call the time T, then the number of nuclei that will disintegrate for that given time will be

$$dN/dT = -\lambda N$$

□ represents the value of the disintegration (decay) constant of the radioactive material. This value is a physical constant, that is the rate of decay of the material is fixed, cannot be changed, and is unaffected by other factors such as : pressure, temperature, etc.

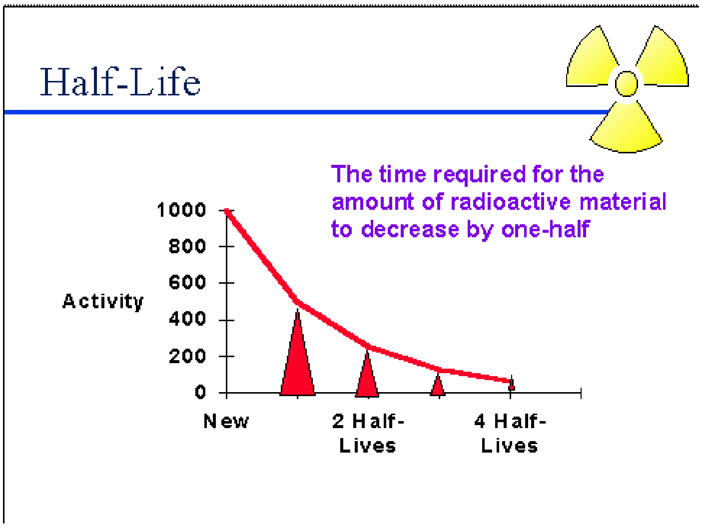
When we solve the above equation, we get

$$N=Noe^{-\lambda t}$$

<u>This is the equation for radioactive decay</u>

No = initial number of radioactive nuclei (at time T = 0)

If we set N = No/2 we can calculate the time in which half the radioactive nuclei will decay. This value is called the physical half-life and depends solely on the material's constant of decay; that is to say, it is also a physical constant characteristic of each radioactive isotope. It is usually referred to as T 1 / 2 p.



In the same way that we define physical half-life, we define biological half-life (T 1/2 b): the time taken by half the quantity of radioactive material that has penetrated a living body to clear away. (Note that this value is not a physical constant. The biological half-life depends on various biological parameters that change from person to person and, for the same radioactive material, between various chemical compounds.)

We also define the effective half-life (T 1/2 eff), a combination of the physical and the biological half-lives. When we speak of the dangers of radioactive materials that are liable to penetrate the body, the effective half-life is the value that interests us. When radioactive material penetrates the body, then on the one hand it continues to decay according to its physical half-life, and on the other hand, it is cleared out of the body according to the biological half-life. Thus, for example, the physical half-life of tritium is about 12.5 years, while its biological half-life is about 12 days. Note, however, that when the type of half-life is not specifically stated, reference is always to the physical half-life.

As stated above, if, in the equation for radioactive decay we set N = No/2, then after solving the equation we obtain the connection between the decay constant and the half-life:

$T\,1/2 = \ln 2/\lambda \rightarrow \ln 2 = 0.693 \rightarrow T\,1/2 = 0.693/\lambda \rightarrow \lambda = 0.693/T\,1/2$

Setting this in the equation for radioactive decay, we obtain:

$$N = No\ e^{-0.693\ T/T_{1/2}}$$

This is the equation that we use in calculation of decay, when we have a given half-life and initial quantity of a material, and the elapsed time.

The use of the number of radioactive nuclei in the equation makes calculation difficult. For this reason, a special unit is established to express the rate of decay of the radioactive material/the activity of the radioactive material – the rate of disintegration is called activity and is measured in units of disintegration per second (dps) and its symbol is **A** (and, in parallel, also Ao).

In the past, activity was measured in **Curies** (Ci), defined as the quantity of radioactive material in which $3.7\text{x}10^{10}$ disintegration's per second. Correspondingly, a **milicurie** (mCi) was also defined as one thousandth of a Curie, and a **micro curie**, one millionth of a Curie μCi, that is to say, $3.7\text{x}10^{4}$ disintegration's per second (dps) or $2.2\text{x}10^{6}$ disintegration's per minute (dpm). Today, a new unit of activity has become common, the Becquerel (Bq). It is defined as: **the quantity of radioactive material in which one disintegration takes place per second, i.e., 1 Bq = 1 dps, and in parallel, 1 Bq = $2.7\text{x}10^{-11}$ Ci and thus 1 Ci = $3.7\text{x}10^{10}$ Bq**

It is now possible to replace the number of nuclei by the activity in the decay equation, thus obtaining:

$$A = Ao\ e^{-0.693\ T/T_{1/2}}$$

A – the activity in Curie or Becquerel units in time T

Ao – the activity in Curie or Becquerel units in time T = 0

Another method of calculating the activity when the initial activity and the half-life of a material are known, is by use of the equation

$$Ao/A = 2^{n}$$

n = the number of half-lives $T/T_{1/2}$

Energy

Radioactive decay is always accompanied by energy. The energy is transmitted to the particles or electromagnetic radiation. The energy can also appear in the form of heat.

We measure the energy level of the radiation in electron volts (eV). One electron volt is defined as the energy gained by an electron when there is a fall in voltage of 1 volt/cm. This is an extremely small unit of measurement: 1eV = $1.6\text{x}10^{-19}$ Joules. The unit is useful for measurement of the energy of radioactive radiation and the physics of atoms and nuclei. We also define larger units, the KeV—1000 times larger, and the MeV, 1 million times larger

Specific Activity

A characteristic value for any radioactive material is its specific activity, defined as the activity obtained from a unit by weight of the material. That is, the units will be either Bq/gr or Ci/gr where gr = 1 gram. The specific activity is solely dependent on the decay constant of the particular radioactive material and is therefore another characteristic constant. For example: to obtain an activity of 1Ci from uranium, we require 3 tons of uranium, but to obtain the same activity from P-32 , we only need 3 micrograms of P-32.

In biological and medical research, specific activity usually has a different meaning. We speak of the specific activity of the level of radioactive labelling of the material. when we produce a molecule labelled, by radioactive material, the process is one of replacing a non-radioactive atom by a radioactive isotope of the same element. Thus, for example, we can exchange some of the hydrogen atoms in water with the tritium isotope. As a result, some of the water molecules will be radioactively labelled. Clearly, the specific activity in this sense, will not be a constant value. Here, the measurement is in units of Bq/mmole or Ci/mmole, that is, the number of disintegration's we can get from each milimol of material. Today, we can obtain materials with different levels of labelling. For instance, THYMIDINE, labelled with tritium, can be obtained with a specific activity of 80, 40, or even 2 Ci/mmole.

Table 2: **The Characteristics of Some Radioisotopes Used in Biological Research**

Isotope	Physical T 1/2	Effective T 1/2	Type of Radiation	Energy of □-Radiation	Energy of □-Radiation	Specific activity (Ci/gr)
H-3	12.3 year	10/day	β	18.6 KeV	–	97000
C-14	5730 year	40/day	β	156 KeV	–	4.6
P-32	14.3 day	14.1 day	β	1.7 MeV	–	286000
S-35	87 day	44.3 day	β	167 KeV	–	42500
Ca-45	165 day	162 day	β	252 KeV	–	17600
Cr-51	27.8 day	26.4 day	β,γ	315 KeV	320 KeV	92000
Rb-86	18.7 day	13.2 day	β,γ	1.78 MeV	1.08 MeV	81400
I-125	60.2 day	41.8 day	γ(x)	–	35 KeV	17000

Units of Radiation

Roentgen (R)

The first unit to be defined was the Roentgen: a dose of exposure to X-rays or □-Radiation that causes one electrostatic charge per cubic centimetre (cc) in dry air. This unit is impractical since it is defined only for X-rays or □-Radiation, and also because it is defined only for exposure in air.

Rad, Gray (Gy)

To refer to all types of radiation, all materials, and the energy that the radiation transmits, an absorbed dose, measured in Rad units has been defined:

1 Rad = 100 erg/gr.: that is to say, when one gram of an exposed material absorbs 100 erg of energy, then the material is exposed to 1 Rad

Today, a new unit is in use, the Gray, defined as: **1 Gray = 1 Joule/Kg**. (Kilograms (Kg) and Grams (gr) are units of weight. Joules and Ergs are recognised units of energy.) Because of the ratio between Joule and Erg and between Kg and gr, 1 Gray = 100 Rad.

Absorbed dose is a useful unit of measurement, but when we try to evaluate damage caused by exposure to radiation, we must take the type of radiation into account, since we know that there are differences between types of radiation in their ionising ability and energy transfer.

<u>Quality Factor</u> (**QF**)

To take account of the type of radiation, the quality factor (QF) has been defined as 1 for X-Rays, γ and β radiation. For α radiation, QF = 20, while for neutron radiation, QF = from 3 to 20, depending on energy level. The significance of this factor is that for the same absorbed dose, we will obtain—in the case of exposure to α radiation—20 times more damage than exposure to γ or β radiation.

<u>Relative Biological Damage</u>

To evaluate the damage to the body by exposure to radioactive radiation, a unit of damage has been defined. For the purpose of calculation, we obtain the level of damage by multiplying the absorbed dose by appropriate quality factor. In the past, the unit of measurement was the Rem, where Rem = Rad x QF.

Today, another unit is in common use, the Sivert (Sv), where:

Sv = Gy x QF   and so   1 Sv = 100 Rem.

The determined unit permits us to evaluate the immediate damage and the delayed damage caused to the body by exposure (internal or external) to radioactive radiation.

<u>The Damage Caused by Exposure to Radioactive Radiation</u>

When our body is exposed to radioactive radiation, ionisation will take place, as occurs in any medium bombarded by radiation. Atoms making up the cells of the body tissues will lose an electron, a free electron and an ion will be obtained. In such a situation, chemical processes will occur between the molecules in the body tissues, the electrons and ions. The final result is the destruction of body cells and, in extreme cases, destruction of tissue. Therefore, it is of great importance to prevent penetration of the body by radioactive materials, since the damage caused will be all the greater when the radiation loses most of its energy within the body, i.e., greater ionisation and damage to a greater number of cells.

The ability of radioactive radiation to destroy cells is also exploited for the good of mankind. The cells most sensitive to radiation are those that constantly divide, and we therefore use radiation to destroy cancerous tumours. To this end, we must expose the relevant body part to a very high dosage of radiation.

The damage so far described is immediate. Another form of damage is delayed damage, also as a result of exposure to radiation. The major form of delayed damage is increased chances of death from cancer in the years subsequent to the exposure. In the case of the exposure of a large population to a high degree of radiation (like the population near the Chernobyl reactor), an increased death rate from cancer can be anticipated.

Nevertheless, we ought to know that the probability of each one of us dying from cancer is, today, 20%. That is to say, about one fifth of all deaths are today caused by cancer. The additional probability due to exposure to radiation is very small, even in cases of quite substantial doses.

The materials and devices used in university work and the types of work, have been chosen so that correct working procedures will ensure that no immediate damage is caused, and that any delayed damage is kept to the very minimum.

In any event, work with radioactive radiation is performed under the control of the Ministries of Labour and of the Environment. In Israel and abroad, permissible limits of exposure have been established. At Ben-Gurion University we are far below the prescribed limits.

Modern life exposes us to many and varied risks much greater than that of exposure to low-level radiation. This is true not only of road accidents, but of exposure to cancer-causing agents in the food we eat, the water we drink, the air we breathe, and in the various chemicals in the cleaning materials that we use. There is no reason to approach exposure to radioactive radiation differently than the way we approach other risks. We must be aware of the risk and know how to reduce it to a minimum. This is true for all dangers as well as those of radioactive exposure.

Detection of Radiation

As noted above, radioactive radiation is characterised by its ability to cause ionisation in the medium through which it passes. This feature is exploited by most of the devices (also known as Counters) that we use to detect and measure radioactive radiation Detectors based on the detection of ionisation are called Ionisation Detectors.

Another feature of radioactive radiation exploited for detection and measurement is the fact that certain materials emit light when they are exposed to such radiation, the amount of emitted light being proportional to the amount of radiation. Such materials are called scintillations. Some of these are solid, such as sodium iodide (NaI) and zinc sulphide (ZnS), and there are also liquid [luminescence] such as various petroleum derivatives as well as some derivatives of oxazoles, of which the best-known and most useful is 2.5-diphenyloxazole, given the symbol PPO.

Ionisation detectors

In every ionisation detector we build a detector that can be likened to a charged electric capacitor filled with a gas and connected to a source of direct current. In such a system there is no flow of current between the poles since the gas is not ionised. When radioactive radiation encounters the detector, ions are formed in the gas, leading to the movement of positive ions to the anode, and of electrons to the cathode, that is, an electric current flows. This flow is very small but can be measured. The strength of the current is proportional to the amount of radiation and its energy. The various types of ionisation detector are distinguished only by the charge that can be obtained. This charge, of course, affects the current produced. The best known detector is the Geiger Counter, and most of the devices used for the detection of radiation incorporate it. Most of the detectors used by the University are ionisation cells of the Geiger type. Another useful type is the Proportional Ionisation Cell.

The main drawback of the ionisation detector is that in order for us to be able to detect and measure it, the radiation must penetrate the body of the detector and ionise the gas. The manufacturers make every effort to make the walls of the device as thin as possible, but because of the characteristics of the various forms of radiation, it is impossible to measure low energy Beta radiation, or Alpha radiation. These detectors are only efficient for the measurement of Gamma and high energy Beta radiation (such as P-32).

Scintillation detectors

We distinguish between solid and liquid scintillation detectors. Solid scintillating materials of various thickness are used to detect various types of radiation. The detector incorporates a crystal that emits light when it encounters radiation, and a photomultiplier.

The role of the photomultiplier is to transform the emitted light into a flow of electrons that can be measured. This is done by a photocathode that responds by the emission of electrons when light strikes it. These electrons are accelerated in the photomultiplier by increasing voltages, and as a result, the number of electrons is multiplied along the device until a significant flow is obtained. The advantage of solid scintillating detectors is their high sensitivity and efficiency. Their disadvantage, as with ionisation detectors, lies in the fact that very low radiation energy cannot penetrate the walls of the device. They cannot therefore detect materials such as H-3 and C-14 that emit low energy radiation.

Liquid scintillators

The most useful method of measuring radiation in biological and medical research employs liquid scintillations. In this case we use scintillating liquids into which we mix the sample to be tested. Thus, a direct contact between the radiation emitter and the liquid is achieved and no problem of penetrating the structure is encountered. This is the only way in which materials such as S-35, C-14, or H-3 can be detected.

Preparation of the sample for measurement and addition to the liquid is performed outside the counter. The counter usually contains two large photo-multipliers between which the sample is introduced, so that they collect the maximum amount of light. The photomultipliers then translate the light into a stream of electrons that can be measured. Today, most of these counters have a multi-channel analyser that can differentiating the size of current produced by each radioactive disintegration in the sample. The analyser gives us the numbers obtained from each pulse of current. Since there is a direct connection between the energy emitted in radioactive disintegration and the size of the pulse of current obtained, we can actually translate the readings to get the number of counts for any energy level. Because every radioactive material has its own characteristic energy level, we can identify the material being tested as well. In modern counters it is usually possible to test at least three levels of energy (“windows”) simultaneously, so we can test samples that contain a mixture of three materials, if there are differences in their energy levels. For instance, it is quite easy to test a sample containing H-3, C-14, and P-32, but C-14 and S-35 cannot be tested simultaneously. (See Table 2 for energy levels.)

The subject is made rather more complex by the fact that the Beta radiation we measure is not monochromatic. For example, tritium—H-3—has Beta radiation with a maximum energy of 18 KeV, but the average energy level of Beta radiation is just 5.6 KeV. As a result, we will get a partial overlap between some of the counter’s measurement channels and this fact must be taken into account when we measure more than one material at the same time.

The advantages of using liquid counters include:

- The ability to detect low energy radiation.
- Highly efficient measurement (up to 90% for C-14 and up to 70% for H-3).
- The ability to test samples with double or triple labels simultaneously.

The disadvantages in using this type of counter derive, in most cases, from mutual reactions between the materials making up the sample, and those in the liquid scintillation. The most prominent problem is the absorption of some of the emitted light in the sample itself before the light reaches the photomultipliers. Understandably, this reduces the efficiency of the measurement. The phenomenon is known as Quenching. Sometimes the cause is the build-up of turbidity in the sample, occasionally to the degree that it becomes viscous. This phenomenon can be easily demonstrated by adding water to the scintillation. Usually (depending on the type of liquid), up to 20% water can be added, but above this percentage the mixture becomes increasingly turbid as more water is added until it turns viscous. Another factor that may cause problems is a change in colour caused by a reaction between the scintillating liquid and the sample under test. Here, too, some of the light will be absorbed, reducing efficiency.

There are various methods of combating the problem of quenching, but it cannot be totally overcome. It is important to be aware of the phenomenon and although it is impossible to avoid, we can usually determine the level of quenching with some efficiency. One method is to add a measured quantity of a radioactive material to the sample under test. The ratio of the actual reading given by the device to the reading that ought to be given in the absence of quenching is obtained, enabling the readings to be adjusted. This method is known as Internal Standard.

In parallel to quenching in the sample under test, there is an opposite phenomenon—an excess emission of light, not caused by radioactive radiation, but by various processes taking place between the sample and the scintillating liquid. Such processes, including Chemi-luminescence and Phosphorescence, cause the emission of light unconnected with radioactivity. Here , too, we must be aware of the problem, which can be overcome by choosing the appropriate liquid for the sample to be tested.

The excess emission of light in the scintillating liquid can be easily demonstrated. First, we take a flask containing pure scintillating liquid (without any radioactive material) and measure it using a counter to obtain a background reading. We then expose the flask to sunlight or to a light source (not fluorescent) for a minute or even less, and re-measure the liquid, we will obtain a higher count. (If we then wait a sufficient time, the count will go back to its background level.)

THE CERENKOV METHOD

When charged particles move through an agent at a higher speed than the speed of light in the same agent (note that the speed of the particles is still lower than the speed of light in a vacuum), we get an emission of blue light known as Cerenkov Radiation. In certain cases, this phenomenon can be exploited to detect radioactive radiation . The method is only usable for high-energy charged particles, i.e., in biological research, primarily for P-32 (which emits high energy Beta radiation).

In this method we directly measure the light emitted without a scintillating liquid, and water is usually employed as the agent in which the light is emitted. The photomultiplier in the counter reacts directly to the emitted light and the sample can thus be measured. (In general we get the reading in a window suited to H-3.)

The advantage of the method lies in the saving and convenience in non-use of a scintillating liquid, and also in the ability to use it when reactions occur between the liquid and the sample.

The disadvantage is that the method is limited to certain materials and has a relatively low detection efficiency. (It is generally assumed that the efficiency is only half of that obtained with a scintillating liquid.)

DETECTION OF RADIATION USING PHOTOGRAPHIC FILM

The first detection of radioactivity was made by photographic film. From then and to this day, we use photographic film to detect radiation. As with any electromagnetic radiation (for our purposes, this is also true of radioactive radiation of charged particles such as Alpha and Beta radiation), radioactive radiation causes the fogging of photographic film. The degree of fogging is proportional to the amount of radiation to which the film is exposed.. We exploit this property in various areas of research in biology and medicine, to detect and measure radiation, and to follow various materials that have been labelled by radioactive tracers. The method is called Autoradiography.

SUMMARY

Different people relate to working with radiation in different ways. There are those with exaggerated fears and they will have the most accidents/mishaps. On the other hand, there are those who have no worries at all and, on the contrary, ignore the dangers of exposure to radiation. Both attitudes are unjustified and may have their source in the fact that, unlike other dangers, radiation can not be felt by our senses.

The correct attitude to radiation and its risks is to treat it like other dangers we face in the modern world. We must make an effort to reduce the dangers and to learn how best to work with radiation as safely as possible.

How can we most benefit from radioactive radiation while keeping risks to a minimum? It depends, first and foremost, on ourselves, on each individual worker. We have no miracle solutions. In what follows, we will detail ways and means, but the most important rule is **CONTINUOUS AND SCRUPULOUS ATTENTION TO WORK ACCORDING TO THE PROCEDURES LAID DOWN IN THIS HANDBOOK**.

In working with radioactive radiation, we distinguish—in terms of danger—between two kinds of work: on the one hand, there is work with sealed radioactive sources and with radiation-emitting devices, in which the main danger is exposure of the body to radiation coming from a source outside the body. In such a case we talk of the dangers of radioactive radiation. On the other hand, in using unsealed radioactive materials—powders, liquids and gases, the main danger arises from the penetration into the body of a radioactive material, and the exposure of the body to internal radiation. In this case we refer to the dangers of radioactive contamination.

A further type of danger we must take into account is that of damage to the environment, i.e., the uncontrolled spread of a radioactive material into the surroundings by spilling a radioactive material down the drain, or by dumping it into the regular garbage. We must also prevent this kind of danger.

How can we reduce our exposure to radiation? As noted above, the principle means is to follow closely the procedures laid down. In general, we can say that in order to reduce exposure to external radiation, we must try to use as small quantities of radioactive materials as possible, for as short a time as possible, and as far away as possible. In addition, we can interpose shielding (suitable material that will absorb part of the radiation) between us and the radiation source.

How can we reduce internal exposure /penetration of the body by radioactive materials? In this area there are no simple rules. Radioactive materials can enter the body by inhalation, swallowing, through the skin, or open wounds. We must take various measures to ensure that this does not happen. Some of the effort relates to the building in which we are working and the devices we are using. A well organised and orderly laboratory with washing routines, fume-hoods, work areas, equipment for working with liquids, overalls, gloves, and so on. But here, too, the principle means is to follow closely the procedures laid down. Strict adherence to procedures such as the prohibition of eating and drinking in the laboratory, or of use of the mouth for the taking of samples, in addition to the scrutiny of the person and of the work area—these are just some of the safety procedures. We must all realise that the worker who does not pay attention to safety procedures endangers not only him or herself, but the other personnel in the laboratory and visitors to it.

Using ionising radiation can be safer
if we all adhere to procedure.

In this brief survey, I have tried to convey to the reader the understanding that using radioactive materials can be safe. Of course, we have much more to learn about the subject. After you have learned the procedures laid down in the continuation of this handbook, and have passed the form with your personal details and details of the planned work, you will be invited to take part in a short training session on the subject of safe working with radioactive radiation . Only after the training session and after you have been instructed by the person in charge of the laboratory regarding work methods and equipment, will you be entitled to begin your work with radioactive radiation, and only on condition that the work is conducted in accordance with the safety procedures.

Keep this handbook with you and you will find it useful as you proceed with your work. You can also turn to me with any question regarding use of radioactive radiation (telephone numbers are given further on.).

SAFE WORK!

- **The safety procedures were written by the Radiation Safety Officer and the researchers of Ben-Gurion University.**

- **You must perform your experiments exactly according to the defined procedures!!!**

- **If for any reason you can't do your experiment according to one or more of the procedures-call Radiation Safety and together we will find a safe alternative for conducting your experiments**

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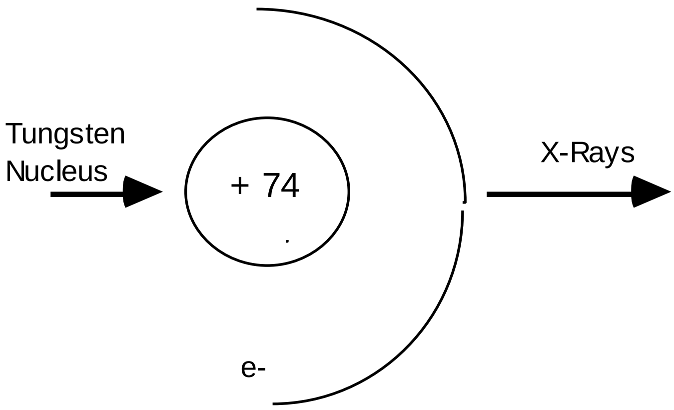
Working with X-Rays

X–radiation was discovered by Roentgen in 1895. It was discovered by accident while work was being done on an electron tube at high tension. The outstanding property of X–radiation was that it penetrated various materials and so its principle use was the viewing of internal parts of systems including the human body. Its use best-known today by the general public is in the field of medical diagnostics but it is also widely used in various scientific devices. The veterinary hospital has X-ray machines for medical use, but most of the devices at the University are designed for scientific research and not for medicine.

Historically, Gamma-rays were discovered about the same time as X-rays. Their names were given to them before anything was known of their properties. Only later was it discovered that both types of radiation are electromagnetic, so that at the same energy level X– and Gamma–radiation are identical. Today the difference in names only indicates the difference in the radiation source, and not in their properties.

Gamma-radiation is emitted by the breakdown of the nuclei of unstable materials at such energy levels that Gamma-radiation is regarded as radiation emanating from the nucleus of the atom. On the other hand, X-radiation is emitted as a result of processes occurring outside the nucleus. In principle, there are two ways of obtaining X–radiation:

The first results from the reduction of electron energy levels within the atom, and the second is the result of energy loss by charged particles when they are stopped by the medium. It is the second method is that exploited in medical and scientific devices.



In Figure 1 we see an accelerated electron approach the electric field of a heavy nucleus such as tungsten (with 74 protons). As a result, the electron is slowed and changes its direction, i.e., loses energy. This energy is emitted as X–radiation

It is usual to call this radiation Bremsstralung (deceleration) because the electron is slowed in the process of emission of energy. In theory, such an electron can lose all of its energy, that would be converted to X–radiation. In practice, the electron loses only part of its energy. An important property of X–radiation obtained in this manner is that the X–radiation is continuous, i.e., over a continuous range of energies and not monochromatic.

In the devices that we use, X–radiation is obtained in the above described way. We accelerate electrons which then bombard a target made of heavy material: the resultant stopping of the electrons produces the X–radiation.

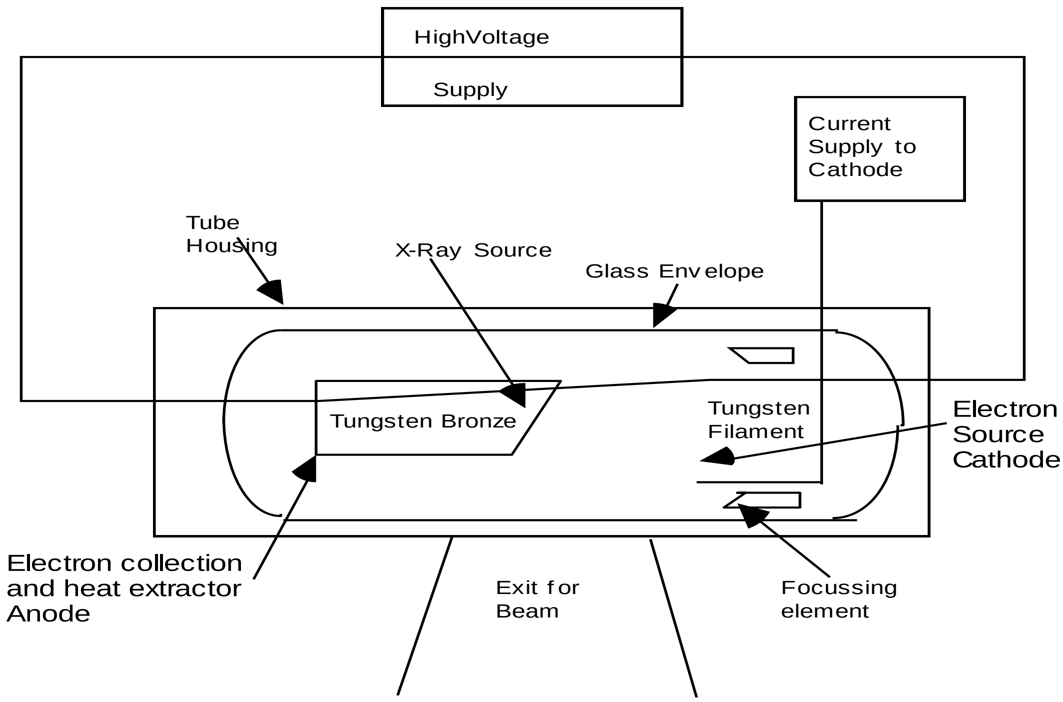
As noted, the other way of getting X–radiation is the reduction in energy levels of electrons within the atom. Such X–radiation is unique to each element. There are a number of methods by which we can cause electrons to jump to a lower energy level. In every method, reference is, in the first instance, to the exit of one electron from one of the atom's levels. The empty space will be filled by another electron that goes down an energy level, accompanied by the emission of X–radiation.

We have seen that radioactive radiation is characterised as ionising radiation , that is, as radiation capable of causing electron emission from the atom. In general, the electron exits the outmost level, in which case there is no reduction in energy level by an electron and no X–radiation is emitted. Instead a process of internal conversion occurs when Gamma-radiation is emitted from the nucleus, causing an electron to exit one of the interior levels; this then leads to a reduction in energy level of an electron and the emission of X–radiation. Another process is called electron capture in which an electron from an inner level is captured by the nucleus, again leading to the reduction in energy level by an outer electron and the emission of X–radiation. In both cases, the result is single X–radiation at low energy.

In the devices we use, X–radiation is obtained by the deceleration method described above. Figure 2 illustrates schematically the main elements of a Roentgen tube.

Electron Source: A filament of tungsten that is heated by an electric current to a temperature of 2,000°C. At such a temperature, a massive emission of electrons is created. The current that we measure by the device is the flow of electrons in the tube when: 1mA=6.25x10^{25} electrons/sec.

High Voltage Supply: High voltage supply in order to create an electric field in which the electrons are accelerated and gain energy. The electron energy is in line with the accelerating tension, so that if we have a voltage of 80Kv, we speak of electrons at an energy level of 80KeV.



Target: The electrons bombard a target made of tungsten. Since only part of the electron energy is converted into X-radiation, much heat is created in the target, and so a suitable means of cooling it must be supplied. The proportion of electron energy converted into X-radiation is relatively low. An approximate equation gives 10^{-3} x atomic weight of the target x electron energy = X-radiation energy

Collimator: a device used to limit the size, shape and direction of the primary radiation beam.

Filter: X-radiation is created at continuous energy levels unsuited to the required application. To obtain X-radiation at the specific energy level needed, we use a filter that causes the deceleration of the initial radiation and the emission of secondary beam determined by the material of which the filter is made. The filter also reduces the power of the radiation obtained.

Tube Housing: Prevents escape of X-radiation in unwanted directions. What we finally get is X-radiation at a specific energy level that can be used for the application.

The university has devices that are used as diffraction meters. In these devices, X-radiation hits crystals and the dispersion of the radiation is measured. In devices of this type there is no open radiation. The unit is usually constructed in such a way that no leakage of radiation to the outside. In another type of device, some of the radiation is open. Clearly, the danger from such a device is much greater.

In both types, we use a low-energy focused beam of relatively small diameter, but at high power. Note that we refer here to a beam of some 10,000 Roentgen per second. At this power level, exposure of fingers or hands would cause immediate damage. Even after the beam has been collimated it still has a power of 500 Roentgen per minute. In the dispersed or secondary beam the power is much reduced. As far as we can, we must avoid planning or executing experiments involving open radiation. If it is unavoidable, suitable shielding must be employed to prevent escape of radiation to the outside. Before operating the device, you must ensure that the shielding is in place. Operation without the shielding is prohibited. Unfortunately these devices do not have an automatic cut-off to eliminate misuse, and therefore it is the responsibility of the operator to ensure that the shielding is in place before use. With such devices it is the practice to test the concentration of the beam with a fluorescent screen. Great care must be taken during such a test. Exposure of the hands must be prevented and the screen must be attached to a long arm. The head must never be inserted to look at the screen, and suitable mirrors must be employed. It must be remembered that above the shielding there is usually significant radiation resulting from reflection and dispersion of the radiation.

One can use X-Ray devices in safety as long as the safety precautions are followed. An important rule is never to carry out any action if there is a chance that you will be exposed to a direct or reflected beam while the device is switched on. The device must be switched off before any such action!

Another no less important rule is to strictly follow and operate the safety measures built-in to the device. All the devices have integral cut-off switches that prevent operation if there is no test unit (the holder that contains the item to be exposed to the radiation) in place in the beam aperture. The device also cuts out when lids or shields are opened. It is absolutely forbidden to try to circumvent or disable these switches! In every known case that significant exposure to radiation in an X-Ray device, it has been found that either the operators had disabled safety devices, or the devices were not in working order.

As can be seen, we are dealing with complex devices that carry some degree of danger. Therefore, their operation requires technical training and knowledge of safety measures. For this reason personnel lacking the requisite training and authorisation must not operate the devices. In particular, it is forbidden to try to alter or change the devices' working conditions.

Any change in, repair to, or service of, the devices must be carried out solely by authorised personnel! The device must be checked for leakage of radiation after every change, maintenance, or repair.

A simple and effective safety measure is to test the devices with a radiation detection instrument as often as possible, and also with the standard daily operation of X-ray devices. At the University today, nearly all the devices have a detection instrument close at hand, which must be utilised. In any case of a mishap, accident or breakdown, the Radiation Safety Unit must be informed.

In order to check an X-radiation device for leakage , we use a detection instrument based on the Geiger counter principle. Such an instrument is not designed to measure X-radiation and it therefore gives an exaggerated response, but we get a higher degree of efficiency and sensitivity when we are interested not in the quantity, but only in the quality (that is, is there leakage or not?).

It is recommended that X-ray devices be checked immediately after each operation. If there is the slightest suspicion of radiation leakage, operation must immediately cease and the Radiation Safety Unit must be contacted. A suitable instrument can measure whether the leakage is significant or not.

In most existing devices the cause of the leakage can be repaired and even if we measured only an insignificant amount of radiation, it is mandatory that we take care to stop the leakage. Usually the problem arises from inexact instalment of the test unit. In such cases the simple operation of tightening a screw or closer fitting of the unit is usually enough to prevent the leakage. In the case of devices that cannot be dealt with in this way, one can install suitable shielding. Due to its low level of energy, X-radiation can easily be stopped—a few millimetres of lead are sufficient. In any event, the shielding can only be installed after checking by a Radiation Safety technician, and only it has been verified that there is no other way to stop the leakage.

The detailed safety regulations accompanying to this handbook are intended to ensure safe working. They must be strictly adhered to. Remember that a worker who breaks the rules endangers not only him or herself, but whoever uses the device afterwards, and whoever works in the vicinity.

At the entrance to every room in which an X-Ray device is installed, there is an illuminated warning placard. You must switch the placard's light on before operating the machine. In principle, there is no point in standing beside the device while it is in operation. On the other hand, you must not leave the room unattended during operation of the device. You must either remain near the door or lock it. All operators must wear a badge for surveillance after exposure. If something goes wrong, or there is a suspicion of any kind of failure, operation of the machine must stop immediately. In such an instance, there is no need to approach the machine, and the electric current should be switched off, either by pressing the emergency button installed in some of the rooms, or by turning off the electricity to the room from the control panel found at the entrance to every room. If this is impossible, summon an electrician who will cut off the electrical supply to the room. In the case of any mishap or suspicion of mishap, you must inform the Radiation Safety Unit at once.

As with any industrial or laboratory equipment, operating and using X-Ray emitting devices involves a measure of danger. As noted above, strict adherence to the rules laid down will ensure safe operations without harm to the personnel. See later, the regulations for working with radiation emitting devices!!

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Tables

1 – Standard signs for scales of measurement

m	milli	10^{-3}	E	exa	10^{18}
u	micro	10^{-6}	P	peta	10^{15}
n	nano	10^{-9}	T	tera	10^{12}
p	pico	10^{-12}	G	giga	10^{9}
f	femto	10^{-15}	M	mega	10^{6}
a	atto	10^{-18}	k	kilo	10^{3}

2 – Units

Connection	Old Unit	New Unit	Size
1 Bq= 2.70 x 10^{-11} Ci = 27.0 pCi 1 Ci = 3.7 x 10^{10}Bq = 37 GBq	curie (Ci)	bequerel (Bq) 1 bequerel = 1/s	Activity
1 Gy = 100 rads 1 rad = 0.01 Gy = 10 mgy	rad (rad)	gray (Gy) 1Gy = 1J/kg	Unit of absorption
1 Sv = 100 rems 1 rem = 0.01 Sv = 10 mSv	rem	Sievert (Sv) 1 Sv = 1J/kg	Equivalent dose
1 C/kg = 3876 R = 3.876 kR 1 R=2.58 x 10^{-4} C/kg = 258 μC/kg	roentgen (R)	coulomb/kilogram (C/Kg)	Exposure

3-Conversion from Curie to Bequerel

MBq GBq TBq	μCi MCi Ci
1.11	30
1.48	40
1.85	50
2.22	60
2.59	70
2.96	80
3.33	90
3.7	100
4.625	125
5.55	150
7.4	200
9.25	250
11.1	300
14.8	400
18.5	500
22.2	600
25.9	700
27.5	750
29.6	800
33.3	900
37	1000

Example

50 μCi	=	1.85 MBq
200mCi	=	7.4 GBq
1000 Ci	=	37 TBq

kBq MBq GBq	μCi mCi Ci
3.7	0.1
7.4	0.2
9.25	0.25
11.1	0.3
14.8	0.4
18.5	0.5
37	1
74	2
92.5	2.5
111	3
148	4
185	5
222	6
259	7
296	8
333	9
370	10
444	12
555	15
740	20
925	25

0.2 μCi	=	7.4 kBq
5 mCi	=	185 MBq
20 Ci	=	740 GBq

Safety Procedures will protect you!!

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Re: Approval of Staff as Radiation Personnel

(As per University Regulations 09-003)

Definition: a radiation worker is anyone: academic staff, administrative staff, technical staff, or student, who , in the framework of his or her work at any of the branches of the University, uses radiation emitting devices, radiation sources, or radioactive materials.

1. Every radiation worker position will be described “as a radiation worker position” by the initiator on his application to the Manpower Unit for filling the position. These regulations also apply to veteran personnel who, in the course of their employment are required by the University to start working as a radiation worker.
2. The Manpower Unit will refer the worker to the medical services for a medical check-up. The referral must specify that the candidate will be employed as a radiation worker. The medical examination must be carried out before work with radiation begins.
3. The Manpower Unit will refer the worker to the Radiation Safety Unit for training and safety equipment. A safety technician will give the worker a written permit for radiation work. A copy of the permit will be sent to the Manpower Unit.
4. For a student who, in the course of his or her studies for a higher degree, or in order to carry out a final project, must carry out work involving use of radioactive materials and/or radiation emitting devices, must be referred by his or her supervisor to the Radiation Safety Unit for training, and authorisation before work begins.
5. Instructional laboratories for the students will be conducted in accordance with the regulations for “student use of radioactive materials, radiation sources, and radiation emitting devices.”
6. No radiation worker will be employed without a written permit from the Radiation Safety Unit.
7. A radiation worker who has finished work with radiation, or intends to leave University employment, must inform the Radiation Safety Unit. The Manpower Unit will delay any further processing of the worker’s paperwork until a permit is received from the Radiation Safety Unit.

Radiation Safety Unit

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Re: Permit for Work in Radiation Laboratories

Definition: For the purpose of these regulations, a radiation laboratory is any work area in which radioactive sources or materials are used or stored, or in which radiation emitting devices are used.

1. A worker wishing laboratory authorisation for using radioactive materials or radiation emitting sources should submit a written application to the Radiation Safety Unit, with details of the types of material, quantities to be used and to be stored, a brief description of the work, and the names of the personnel who will be employed in the laboratory.
2. A worker wishing to install a radiation emitting device should submit a written application to the Radiation Safety Unit, with details of the type of device, manufacturer, tension and current required by the work, a brief description of how the device is employed, and the names of the personnel who will use it.
3. Application to the Radiation Safety Unit is mandatory before the start of the process of obtaining radioactive materials or radiation emitting devices!
4. When the application is received, a technician from the Radiation Safety Unit will visit the proposed work area and, if necessary, will inform the initiator of any physical arrangements that must be made to the work area (as per the requirements of the Ministries of Labour and Health).
5. After the initiator has informed the Radiation Safety Unit that the preparations have been completed, representatives of the two ministries will be invited to inspect the area and give their certification. NOTE: The process from the receipt of the application to its approval takes time! Apply to the Radiation Safety Unit as soon as possible!
6. No worker must engage in any work involving radiation in a place that has not been certified by the Ministries of Labour and Health. In areas that have received approval, the work must be conducted strictly according to the terms of the certificate. For any departure from the terms of the certificate, approval must be requested from the Radiation Safety Unit.

Radiation Safety Unit

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Re: Procedures for Ordering Radioactive Materials and Radiation Emitting Devices

A . **Procedures for Ordering Radioactive Materials**

1. A university employee who wishes to obtain radioactive materials (including radiation sources) will submit a supply order form for radioactive materials to the chemicals buyer at the purchasing department (see example).
2. The order must clearly indicate the following details: Name of material; Supplier's catalogue number; Manufacturer's name; Agent's name; Name of radioactive material by which the material is labelled (or its chemical sign); and the quantity/activity (in recognised units, mCi, Bq, etc.).
3. A separate order form must be completed for each material. In the case of a standing order, a separate order must be filled out for each quantity of the material to be reordered, noting that a standing order is involved.
4. On receipt of the order, the chemicals stockroom will inform the Radiation Safety Unit. A technician will check to see if the order has necessary authorisation to using radioactive materials including the ordered material, and that the laboratory in which the material is to be used is suitable both for the work to be performed and for the quantities of material involved.
5. If there are no departures from the regulations, the order will be approved (the signature and stamp of the technician will be appended to the order form) and the material will be ordered by the stockroom.
6. If approval of the order is withheld, both the initiator and the stockroom will be immediately notified.
7. The chemicals stockroom will not place an order for radioactive materials unless the order form has been approved by the Radiation Safety Unit.
8. Radioactive materials will only be received by the University solely by the chemicals stockroom. It is forbidden for a worker to receive radioactive materials directly from the supplier! It is forbidden for a worker to order radioactive materials directly from the supplier!
9. When the material arrives, it will be stored in the designated metal cabinet, or in cold storage, if necessary.
10. The chemicals stockroom will notify a technician of the Radiation Safety Unit that the material has arrived.
11. The technician will verify that the material received accords with the order form and the safety regulations.
12. The technician will countersign the receipt form in the stockroom and will pass the material on to the initiator as quickly as possible. The initiator will also append his or her signature to the receipt form. Radioactive materials must be stored in a locked and clearly labelled cabinet.
13. The initiator must not transfer the material to another worker.
14. It is forbidden to introduce radioactive materials or radiation sources to the University other than via the chemicals stockroom.

15, Every departure from these regulations requires prior authorisation from the person responsible for radioactive materials at the University.

B. **Regulations for Ordering Radiation Emitting Devices**

Definition – For the purpose of these regulations, a radiation emitting device is any device that incorporates a radioactive material, or that, as a result of its operation emits radioactive radiation .

1. The initiator of an order for a radiation emitting device will apply to the Radiation Safety Unit before the start of any procedure connected with the order of the device.
2. The Radiation Safety Unit will check that the device meets the safety standards, and that no danger of unmonitored exposure to radiation will result from its installation at the intended site.
3. If the installation of the device requires structural changes or extra installation (such as shielding, signs, etc.), the initiator will be given suitable instructions while the order is passed on to the Ministry of Labour for authorisation of the purchase.
4. After approval by the Radiation Safety Unit, the initiator will fill out a standard equipment order form. The initiator must specify on the order form that reference is to a radiation emitting device. The order will be passed to the Radiation Safety Unit for approval. After countersigning by the Radiation Safety Unit, the form will be passed to the Supply Department.(it will be done in the computerised system).
5. When the device is delivered to the University, the transfer stockroom will inform the Radiation Safety Unit.
6. A Radiation Safety technician will inspect the device and ensure that the location intended for its installation has been properly prepared.
7. The technician will authorise the transfer stockroom to deliver the device to the initiator.
8. A radiation emitting device that arrives at the University without prior approval of the Radiation Safety Unit may result in a lengthy delay in its utilisation. It could happen that the device cannot be installed in the University
9. **THE FIRST OPERATION OF ANY RADIATION EMITTING DEVICE WILL BE CONDUCTED IN THE PRESENCE OF A RADIATION SAFETY UNIT TECHNICIAN. IF THE DEVICE CONTAINS RADIOACTIVE MATERIAL, ALL STAGES OF THE INSTALLATION OF THE DEVICE MUST BE CARRIED OUT IN THE PRESENCE OF A RADIATION SAFETY TECHNICIAN.**
10. Operation of radiation emitting devices must only be conducted by personnel with a permit to do so, in accordance with the conditions of the permit and the operating procedures laid down for radiation emitting devices.
11. A change in the location of a radiation emitting device requires prior authorisation by a Radiation Safety technician.

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Re: General Safety Procedures for Using Radioactive Materials

1. Work with radioactive materials will only be conducted in laboratories that have received a permit for using radioactive materials, and only by personnel authorised for work with radiation. The work will be conducted according to the terms of the permits issued to the worker and for the laboratory.
2. Any departure from the terms of the above permits requires prior approval of the Radiation Safety Unit.
3. Every worker with radioactive materials will maintain an accurate written record of all work done with radioactive materials. The record will include: date, type of material, activity, and special occurrences.
4. In the laboratory where radioactive materials are in use, every worker will wear a lab coat at all times.

5. A worker coming in contact with radioactive materials, or using instruments that comes in contact with radioactive materials, will wear disposable gloves. The gloves must be changed as frequently as possible.

6. Before work commences, the work area must be prepared: absorbent papers must be spread out on the lab tables and trays padded with absorbent material must be prepared. All activities involving radioactive liquids must be carried out in these trays.
7. The work area must be clearly labelled with "RADIOACTIVITY" stickers. These can be obtained from the Radiation Safety Unit.
8. Receptacles for disposal of liquid and solid radioactive waste must be prepared. In laboratory using P-32 , Rb-86 , Na-22 or any other high energy beta or gamma emitters , a proper shielding must be prepared.
9. It is most desirable to reduce the quantity of radioactive material in use to a minimum.
10. AS MANY STAGES OF THE WORK AS POSSIBLE SHOULD BE CONDUCTED IN A FUME-HOOD. WORK WITH THE "MOTHER SOLUTION" (THE ORIGINAL HIGH-CONCENTRATE) MUST ALWAYS BE PERFORMED IN A FUME HOOD.
11. When work is performed with materials emitting high-energy Beta radiation or Gamma-radiation (such as: P-32, I-125, Cr-51, Rb-86, etc.), a portable radiation detector must be at hand. The detector must be suited to the type of radiation and the type of materials being tested. In any doubt exists, consult the Radiation Safety Unit. **<u>It is forbidden to start working if there isn't a proper detector at hand!!!!</u>**

12. In work with materials emitting Beta or Gamma-radiation that can be detected by a portable detector (P-32, I-125, Cr-51, Rb-86, etc.), the worker must check him or herself and the work area as frequently as possible with a suitable detector. The worker must perform a check on him or herself and on the work area before leaving the laboratory and on completion of the work! At the end of the workday, all personnel who were present in the laboratory must be checked even if they did not use radioactive materials.
13. In using materials emitting Beta-radiation that cannot be detected by a portable detector (Ca-45, S-35, C-14, H-3, etc.), "smear" tests of the personnel and the

work area must be performed as frequently as possible! (swabbing the tested area with a moist piece of paper , inserting the paper into a scintillation detector and a radiation count by a suitable device; at the same time a count is made of a clean piece of paper to establish the background level.) **CHECKS MUST BE PERFORMED ON WORKERS AND THE WORK AREA BEFORE LEAVING THE LABORATORY AND ON COMPLETION OF THE WORK! THE FACT THAT THESE MATERIALS ARE DIFICULD TO DETECT DOSE NOT MAKE THEM LESS DANGERUS!!**

14. It is forbidden to smoke, eat or drink, or to use cosmetics in the laboratory. Food must not be stored, drinks must not be prepared , nor utensils for food and drink kept, in the laboratory.
15. **Operations that involve the use of the mouth, such as taking up liquids with a pipette, are prohibited in a radiation laboratory. This regulation applies to all personnel in the laboratory, and on all types of work including using non-radioactive materials!**
16. It is best to use disposable utensils as much as possible. In any event, utensils used with radioactive materials must be kept separate from the other utensils in the laboratory.
17. All equipment that comes in contact with radioactive materials (furniture, utensils, laboratory utensils, etc.), must be labelled by a “radioactive” sticker. Such equipment must not be transferred to another laboratory, or sent for repair in or outside the University without inspection by and approval of the Radiation Safety Unit. Equipment must only be used for its stated purpose.
18. Personnel who have received a radioactivity badge must wear it at all times in the laboratory.
19. In every case of radioactive contamination of a worker, his or her clothing, or the work area, or of a suspicion of the spread of such contamination, and in the event of any mishap, the Radiation Safety Unit must be informed at once—see regulations for dealing with mishaps.
20. Non-disposable towels or wipes must not be used in a radiation laboratory, and solid bars of soap are prohibited. Hands must be thoroughly washed each time you leave the laboratory!!
21. Upon completion of work, radioactive waste must be taken to the collection point. All utensils that have come in contact with radioactive materials must be taken to the washing point. **radioactive WASTE MUST NOT BE ACCUMULATED IN THE LABORATORY! LIQUID WASTE MUST NOT BE DISPOSED OF DOWN THE DRAIN INTO THE SEWER SYSTEM!** Radioactive waste must be dealt with according to the appropriate regulations.
22. Radioactive materials must not be left unattended on worktables, or anywhere else open to unauthorised personnel.
23. Radioactive materials can be stored in a refrigerator, cupboard or fume hood, on condition that the storage unit be kept locked and labelled.

24. A Radiation Safety technician is entitled to enter any laboratory at any time to inspect the laboratory or the personnel. A Radiation Safety technician is entitled to stop any work involving radioactive materials, radiation sources, or radiation emitting devices, if there is any deviation from the safety regulations or danger to the personnel and/or the surroundings.

25 A female radiation worker who becomes pregnant must inform the Radiation Safety Unit as soon as possible. The head of the unit will give written approval of continuation of work with radiation, or will set limits according to the safety regulations (according to female personnel regulations, 1979).

26. It is forbidden to bring students under the age of 18 to work or to study in a radiation laboratory without special permission from the head of the Radiation Safety Unit.

27. Before starting using radioactive materials, the worker must practice and thoroughly prepare all the necessary equipment. Every stage of the experiment must first be practised without the use of radioactive materials. The head of the laboratory must teach a new worker on the laboratory procedures including safety procedures. A new worker must get permission from the head of the laboratory before starting working in the laboratory.

28. The first performance of experiments must only be carried out under the close supervision of the head of the laboratory and of the Radiation Safety Unit. Personnel must obtain permission from the laboratory head before using radioactive materials.

29. A radiation worker must be familiar with the properties of any radioactive material and compounds he or she uses (radioactive properties but also chemical and physical properties). For example, a worker using tritium must know that there is a difference in the level of risk between water labelled with tritium and thymedine labelled with tritium. Equally, every worker must be familiar with any physical change that may occur when working with the material, such as the emission of gas or the production of volatile compounds. **IN ANY EVENT, TO WORK WITH RADIOACTIVE MATERIALS OR COMPOUNDS WITHOUT KNOWING THEIR PROPERTIES IS PROHIBITED.**

30. Radioactive materials can only be ordered according to the appropriate regulations**. A WORKER WHO HAS TAKEN DELIVERY OF A RADIOACTIVE MATERIAL IS RESPONSIBLE FOR IT AND MUST NOT TRANSFER A RADIOACTIVE MATERIAL TO ANOTHER WORKER WITHOUT PERMISSION OF THE RADIATION SAFETY UNIT. INTRODUCTION OF RADIOACTIVE MATERIALS TO THE UNIVERSITY EXCEPT VIA THE RADIATION SAFETY UNIT IS PROHIBITED.**

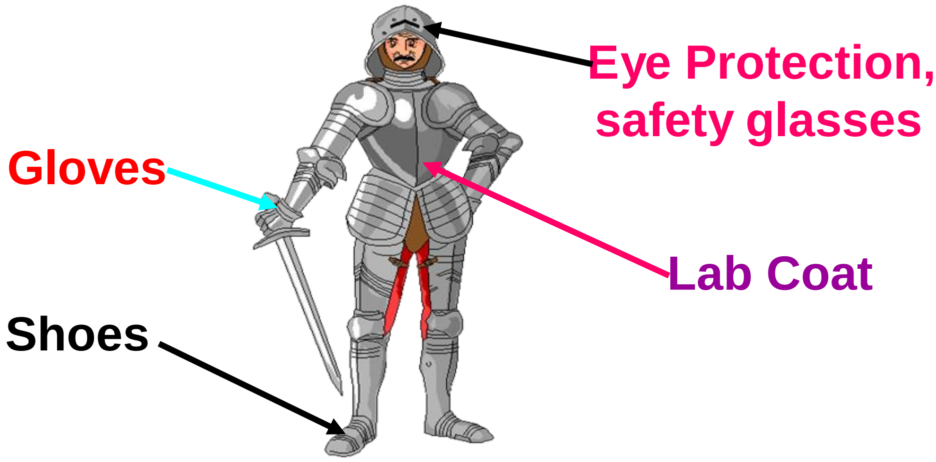
31. The permit issued to personnel for use of radioactive materials applies strictly and **only to liquids**. Experiments using radioactive powders or gases are prohibited without the special approval of the Radiation Safety Unit.

32. The most important general rule regarding using radioactive materials is that safe methods of performing the work should be planned in advance. Mishaps occur when we try to improvise or when, for various reasons, we are pressed for time. Pre-planning will help to eliminate mistakes or accidents.

<u>Note</u> :These guidelines are only general. Detailed regulations governing each aspect of work with radioactive radiation, materials, sources, and radiation-emitting devices, are given further on in this handbook: You will

also find pages of data and work procedures for most of the radioactive materials commonly in use at the University. You can apply to the Radiation Safety Unit on any topic concerning radioactive radiation.

Personal Protecting



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Re: Using Sources of Radioactive Radiation

Definition: In these regulations a source is a solid radioactive material contained in a capsule or adsorbed on another material so that radioactive material cannot be disseminated to the environment. The source is used to supply external radioactive radiation.

1. Work with radioactive sources will only be performed in laboratories with an appropriate permit, and by personnel authorised by the Radiation Safety Unit to use radioactive sources. The work will be performed according to the terms of the permits issued to personnel and laboratories.
2. Work with devices incorporating radiation sources will also be performed solely according to the regulations for operating radiation emitting devices.
3. The ordering of radiation sources will be done according to the regulations for ordering radioactive materials and sources.
4. The introduction of radiation sources to the University without prior approval of the Radiation Safety Unit is prohibited. Radioactive sources must not be transferred from one worker to another or from one laboratory to another.
5. Personnel who have received a radiation badge must always wear it in the laboratory.
6. Each laboratory where radioactive sources are used has its own special procedures. This general order is designed to supplement those individual guidelines. Any departure from the regulations requires prior approval from the Radiation Safety Unit.
7. Sources of radiation will be stored in locations approved by the Radiation Safety Unit. The storage unit will be locked and labelled.
8. In the event of any mishap or suspicion of a mishap, the Radiation Safety Unit must be immediately informed (see regulations for handling mishaps).
9. It is forbidden to leave radiation sources unattended. Every source must be stored under the conditions laid down for it.
10. It is forbidden to send for repair, dismantle, or make changes to, any device incorporating radiation sources without prior approval from the Radiation Safety Unit.
11. Do not touch radiation sources with your bare hands. You must use appropriate tongs.
12. Sources that are stored in a lead pot will only be taken out in the presence of the Radiation Safety Unit.
13. Student laboratories using radiation sources or devices incorporating radiation sources will be performed according to the regulations governing student laboratories.
14. A female radiation worker who becomes pregnant must give written notice as soon as possible to the Radiation Safety Unit.

Radiation Safety Unit

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Re: Operating Radiation Emitting Devices-X ray Machines

The operating of radiation emitting devices shall only be carried out by personnel who have received written authorisation, and as stipulated in the permit.

- It is most desirable to immediately check the device with a Geiger Counter every time it is used. Unless essential , it is advisable not to stand next to the device while it in use. However , the device must not be left unattended!!! If you cannot remain near the device , the door should be locked. Whenever the device is in use , the illuminated sign must be switched on.
- The operator must wear a radiation badge , in the laboratory at all times and must insure that all personnel present are wearing their badges.
- For devices fitted with shielding , the operator must ensure that the shield is in place before the device is operated.
- It is forbidden to disconnect or subvert any of the device's safety equipment (microswitch etc') .
- **After any maintenance or alteration to the device , or after the device has not been in operation for lengthy time , it must only be operated in the presence of a radiological safety technician.**
- Prior approval from radiation safety must be obtained before any non-standard operation of the device , that is the insertion and testing of standard sample.
- When there is a suspicion of a leakage of radiation or a mishap when operating the device the current must be immediately cut off to stop its operation , this can be accomplished by pressing the emergency button or by turning off the main switch in the panel near the entrance , evacuate the room and inform radiation safety . **Do not enter the room or come near the machine if you suspect radiation leakage .**
- Students laboratories that include the use of radiation emitting devices will only be conducted in the presence of an authorised technician or instructor. **It is forbidden to allow students to operate radiation emitting devices by themselves.**
- The purchase of a new device or changing existing device shall only be done after receipt of authorisation from radiation safety. Such a permit should be applied for before the device is ordered.
- A radiation safety inspector has the right to stop any work using radiation emitting device if any of the safety regulations are broken.
- A female worker who becomes pregnant must give written notification to the Radiation Safety Unit as soon as possible.

Radiation Safety Unit

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Re: Radiation Safety Regulations in the Event of Mishap

A . **General**

Definition: In these regulations, a mishap is any situation that may cause danger to personnel or equipment in a radiation laboratory.

In these regulations, a radiation laboratory is any location where work is performed with radioactive materials, radiation sources, and/or radiation emitting devices, as well as any location used to store radioactive materials or waste. Every such place must have a sign “DANGER RADIOACTIVITY!”

These regulations apply to all University Personnel and every person visiting a University Campus.

B. **Mishap/Suspicion of Mishap with a Radiation Emitting Device**

1. Immediately turn off the current to the device by pressing the emergency button (if there is one installed in the laboratory) or by turning off the main breaker of the local electric control panel located near the laboratory. DO NOT APPROACH THE DEVICE IN ORDER TO STOP OPERATION!
2. Withdraw all personnel from the laboratory and surrounding area and prevent other personnel from entering the vicinity.
3. Summon technicians from the Radiation Safety Unit. Stay in place until they arrive.

C . **Mishap/Suspicion of Mishap in Use of a Radiation Source**

1. Withdraw all personnel from the laboratory and surrounding area and prevent other personnel from entering the vicinity.

DO NOT APPROACH THE VICINITY OF THE SOURCE!

2. Gather all personnel who were in the laboratory at the time of the mishap in a nearby room
3. Summon technicians from the Radiation Safety Unit. Stay in place until they arrive.

D Spread/Suspicion of Spread of Radioactive Contamination

1. The worker who discovers or suspects a spread of radioactive contamination will take care to move all personnel to a nearby room and will prevent other personnel from entering the vicinity.
2. Summon technicians from the Radiation Safety Unit, and at the same time start to check the workers and the work area.
3. All personnel who were in the laboratory at the time of the mishap will wait in place until the Radiation Safety personnel arrive. To leave the vicinity without permission of the Radiation Safety Unit is prohibited.
4. A worker who checked him or herself and discovered radioactive contamination will immediately inform the Radiation Safety Unit (preferably via another worker). In any event, the worker must not leave the work area if there is any suspicion of contamination of the worker or his clothing.
5. Where contamination was found on an overall or work coat, shoes or personal clothing, the contaminated items must be removed, the body must be checked

with a suitable instrument, and if found to be clear, the worker must put on a clean overall or other clean clothing.

6. If radioactive contamination is found an parts of the worker's body, carefully try to clean the affected area with soap and water. Under no circumstance try to clean the area with cleaning materials or by rubbing, except in the presence of the Radiation Safety personnel.

E. A Fire in a Radiation Laboratory

1. In the event of a fire breaking out in a laboratory where radioactive materials or radiation sources are used, immediately inform the Radiation Safety Unit as well as the Fire Department. Try to prevent the fire spreading to the radioactive materials. When the firemen arrive, inform them that the fire involves radioactive materials.
2. If the fire occurs in a laboratory that has a metal sign with red letters on a white background, on which is written:

RADIOACTIVE SOURCES
IN CASE OF FIRE, CALL AT ONCE
1. PERSON IN CHARGE OF LABORATORY TEL: ....
2. RADIATION SAFETY UNIT TEL: ....
3. HEAD OF RADIATION SAFETY UNIT

QUIT THE LABORATORY AT ONCE, SUMMON THE FIRE DEPARTMENT, AND REFRAIN FROM ANY ACTIVITY IN THE LABORATORY UNLESS THE PERSON IN CHARGE OF THE LABORATORY, OR PERSONNEL FROM THE RADIATION SAFETY UNIT ARE PRESENT. WHEN FIREMEN ARRIVE, DRAW THEIR ATTENTION TO THE SIGN.

IN ANY CASE OF MISHAP OR SUSPICION OF MISHAP INFORM THE RADIATION SAFETY UNIT IMMEDIATELY!!!

0528795999

95999 from inside the university.

61555 the security department .

Radiation Safety Unit

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Re: Regulations for Handling and Disposal of Radioactive Waste

A. **General**

Definition: In these regulations, radioactive waste is waste from materials or equipment that have come in contact with radioactive materials, and for which there is a suspicion that it may be contaminated by radioactive materials.

1. **Collection points**: Collection points for radioactive wastes have been set up for the use of University personnel.

- a collection point at the old campus (Bet Hias)
- a waste room at the new campus, near Building 63
- a collection point in the Institute for Applied Research
- a waste room in the Pathology Building of Soroka Hospital
- a waste room in the new Faculty of Medicine building of Soroka Hospital, 6th floor
- a collection point in the Blaustein Institute for Desert Research, Sede Boker.
- wastes rooms on every floor of the Faculty of Medicine building.
- wastes rooms on every floor of the life Science building.

At each collection point there are a number of drums with polyethylene sacks for wastes collection.

2 **Disposal of Waste**

Removal of radioactive wastes from the laboratory to a collection point will only be performed by personnel who have a permit to work with radiation (under no circumstance must this work be given to cleaners). Removal from the collection points will be only performed by technicians from the Radiation Safety Unit. The Radiation Safety Unit must be informed when the drums are full.

3. **Contaminated Animals**

Removal of contaminated animals will be carried out only by arrangement with and instructions from the Radiation Safety Unit. DO NOT DISPOSE OF LABORATORY ANIMALS OR ANIMAL PARTS IN THE COLLECTION POINT DRUMS!

4. **Sources**

It is forbidden to dispose of sealed sources of radioactive radiation even after they are no longer usable. Their disposal must be arranged with the Radiation Safety Unit.

5. **Sacks for Radioactive Waste**

It is essential to remove radioactive waste only in the special sacks supplied for that purpose. The sacks are made of a thick plastic and are clearly labelled. (Laboratories will obtain the sacks from the University Chemicals Stockroom.) The sacks are meant for all types of radioactive waste. (containers with liquid wastes absorbed in vermiculite will also be placed in the sacks, as well as material that has undergone sterilisation.)

6. **Radioactive Waste with Sharp Points**

Radioactive waste with sharp points (syringes, glass fragments, etc.) may cause the sacks to tear and can injure the personnel handling the waste. Do not dispose of unguarded syringes or any other sharp waste in the sacks. A syringe will only be disposed of when it has been returned to its original packing. If that is impossible, collect the syringes in a thick metal or plastic box, seal the box carefully, and only then place it in the sacks. Do the same for any other sharp waste. (It is important to note that such instructions also apply to non-radioactive waste.)

7. **Infectious, Carcinogenic or Biological Radioactive Waste**

Biological radioactive waste or radioactive waste that is also carcinogenic or infectious (including animal wastes and blood) must be sterilised before disposal. (This regulation also applies to such types of waste when they are non-radioactive, in accordance with Regulation No. 26: “Use of Contaminating Materials” in the University Handbook of Safety Regulations.) Under present conditions at the University, sterilisation can be carried out in an autoclave or by chemical means.

8. **Departure from Regulations**

In special circumstances, when it is not possible to follow procedures, you should apply to the head of the Radiation Safety Unit. Every departure from regulations requires the prior permission of the Radiation Safety Unit.

B. **Disposal of Solid Waste**

1. In every radiation laboratory there is a labelled and closed waste bin for the disposal of radioactive waste. Inside the bin you should find an appropriate sack.
2. Do not dispose of regular waste in the bin meant for radioactive waste.(disposal of radioactive waste is very costly to the University and you must try to keep the volume of such waste to a minimum).
3. IT IS FORBIDDEN TO THROW RADIOACTIVE WASTE INTO A REGULAR WASTE BIN!
4. When a bin is full of radioactive waste, the polyethylene sack must be sealed with sticky tape.
5. A sticker with the name of the laboratory and the date of removal must be affixed to the sack.
6. A laboratory worker must remove the sack to one of the collection points and place it in a drum.
7. Do not accumulate radioactive waste in the laboratory . Remove it as often as possible.

C. **Disposal of Liquid Waste**

1. DISPOSAL OF LIQUID RADIOACTIVE WASTE DOWN TO DRAIN IS PROHIBITED!
2. Liquid waste should be disposed of in plastic containers containing vermiculite (a material designed to absorb liquids).
3. Take care that no unabsorbed liquid remains in the container.
4. If there is any suspicion of the emission of gases, the open container, without its cap, should be placed in a fume hood for 24 hours before removal.

5. Do not put oxidising/acidic materials with reactive materials in the same container. Any material that is liable to react with another material should be put in a separate container.
6. Flasks, bottles or containers for the disposal of liquids must be made of insoluble material that does not soften or is in any way affected by the liquids it contains. The flask/container must withstand high temperature and degradation. These requirements also apply to the flask/container cap.
7. Flasks, bottles or containers for disposal of liquid radioactive waste must be appropriately labelled. (Remove any existing label and affix a radioactive sticker.)
8. ACCUMULATION OF LIQUID WASTE IN THE LABORATORY IS PROHIBITED, LIQUID WASTE SHOULD BE COLLECTED IN CONTAINERS WITH AS SMALL A VOLUME AS POSSIBLE, DEPENDING ON WORK REQUIREMENTS. THE CONTAINERS SHOULD BE REMOVED FROM THE LABORATORY AS OFTEN AS POSSIBLE. IN ANY EVENT, NEVER USE FLASKS/CONTAINERS WITH A VOLUME OF MORE THAN 5 LITERS.
9. A container that is full must be carefully closed, the cap should be sealed with sticky tape. It should be placed an a sack designed for the disposal of radioactive waste, and the sack sealed with sticky tape.
10. A sticker with the name of the laboratory and the date of removal must be affixed to the sack.
11. A laboratory worker must remove the sack to one of the collection points and place it in a drum.

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NOTIFICATION TO THE RADIATION SAFETY UNIT

IN EVERY CASE OF MISHAP OR SUSPICION OF MISHAP THE RADIATION SAFETY UNIT MUST BE IMMEDIATELY INFORMED.

A. Head of the Radiation Safety Unit: Michal Baram, Telephone at work:

(08) 6461314 (61314)

Mobile 0528795999

95999 from inside the university. 61555 the security department.

Assistant Head: Anatoliy Rodnianskiy, Telephone at work: (08) 6472489 at home 0547256824.

B Secretariat of the Department of Safety, Telephone: (08) 6461550

C Heads of laboratories:

A list of all heads of radiation laboratories can be found in the following locations:

1. Maintenance centre - Main University Campus
2. Security Centre, Main University Campus
3. With Head of Buildings and Works Department
4. With Head of Maintenance Department
5. Office of Radiation Safety Unit,- Main University Campus, Building 63, Room 110.

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Re: Employment of Students with Radioactive Materials, Radiation Sources, and Radiation Emitting Devices

A. **EMPLOYMENT OF STUDENTS AS RADIATION WORKERS**

1. A student who, for his or her final project, regularly works with and uses radioactive materials/radiation sources/radiation emitting devices, will be regarded as a permanent radiation worker as defined by the safety regulations, and all the safety regulations laid down by the University will apply to the student.
2. The person responsible for the laboratory/device will inform the Radiation Safety Unit of the intention to employ students in the use of radiation and will submit their names in writing before work with radiation commences.
3. The safety regulations and University rules prohibit work with radiation for anyone who has not received the necessary training and permit from the Radiation Safety Unit.
4. In order to prevent delay in the start of work, the Radiation Safety Unit should be informed of the intention of working with radioactive radiation as soon as possible.
5. The person responsible for the laboratory/device is legally responsible for the safety of personnel in his/her laboratory . Allowing unauthorised personnel to work with radiation is against the rules and exposes the laboratory head as well as the University to possible legal action.
6. We must all be aware that most of the accidents and dangerous occurrences, involving use of radiation, that have taken place in the University in recent years happened to personnel unauthorised by the Radiation Safety Unit, but who were nevertheless allowed to perform such work.
7. Before commencement of work, the laboratory head will inform the Radiation Safety Unit of any students involved, even if they are only to work for a short time. Such cases will be looked into according to the type of work and level of danger, and in each case the appropriate guidelines will be issued.
8. Teaching labs that use radioactive radiation will be carried out according to the procedures laid down in section B (below)of this regulation.

B. **TEACHING LABS FOR STUDENTS**

The following procedures will apply to students who, in the course of their studies, receive instruction in laboratories that use radioactive materials, radioactive sources, or radiation emitting devices:

1. Holding instructional labs with radiation with students requires prior permission from the Radiation Safety Unit.
2. Such labs will only be held in laboratories authorised by the Radiation Safety Unit for work with radioactive materials, radioactive sources, or radiation emitting devices.
3. The lab initiator/person responsible for the course/lecturer will fill out the request form for instructional lab work involving radiation with students (see attached example) and will send it to the Radiation Safety Unit as soon as possible.

4. The head of the Radiation Safety Unit will ensure that in carrying out the lab, there is no departure from either the safety regulations or the permit for the lab. The head of the Radiation Safety Unit will determine such safety procedures as may be necessary.
5. The practical work performed in the lab will be performed in accordance with all the radiation safety procedures in effect in the University, under the responsibility of the lab initiator and the instructors.
6. The lab initiator will also inform the Radiation Safety Unit of the date of the preparatory lab.
7. The lab initiator must ensure that the instructors who will work with the students during the lab are experienced in radiation and have the permits from the Radiation Safety Unit for such work.
8. The Radiation Safety Unit must be immediately informed of any mishap or suspicion of mishap in the laboratory, under the responsibility of the lab initiator and the instructors.
9. Appropriate notification forms for labs can be obtained from the Radiation Safety Unit.

Radiation Safety Unit

Re: Notice of Instructional Lab for Students with
Radioactive Materials, Radioactive Sources, or Radiation Emitting Devices:

Name of Lab Coordinator/initiator .... Department ………………Lab scheduled for: Date .... Starting time .... Finish time ....

Lab location...Names of Lab Instructors……………………...

Preparatory lab scheduled for: Date .... Time ....

Please supply the following details according to the type of work (materials/sources/devices)

1. **USING RADIOACTIVE MATERIAL**

Types of Material: .... General Activity in Lab: ....…

Activity for each student ....

Description of actions carried out by students…………………………………………….

....……………………………………….

....

2. **USING RADIATION SOURCES**

Description of types of sources and activity of each source……………………………..

....……………………………………………………….

Description of actions carried out by students……………………………………………

....

....

3. **USING RADIATION EMITTING DEVICES**

Types of device: ....…..............

Description of actions carried out by students……………………………………………

....……………………………………….

....

Name of notifier .... Signature ....

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Re: Medical Tests for Radiation Workers

1. Medical tests for radiation workers will be carried out according to the regulations (Administrative Regulation 05-017).
2. Medical tests for radiation workers will include, in addition to regular tests: urine test to discover any radioactive materials, blood tests and eye tests.
3. The head of the Radiation Safety Unit is entitled to order further medical tests at any time as he sees fit.
4. PERFORMANCE OF THESE TESTS IS COMPULSORY. THE WORK PERMIT OF A RADIATION WORKER WHO DOES NOT UNDERGO THE TESTS WHEN REQUIRED WILL BE IMMEDIATELY WITHDRAWN.
5. The person responsible for the laboratory/device must ensure that personnel come for the tests at the arranged time.
6. Urine tests to discover radioactive materials are carried out at the University 3 to 4 times per year. Personnel asked to submit urine samples must prepare them at the time arranged. Personnel who fail to submit their samples at the time arranged will have their permits immediately withdrawn.
7. A new radiation worker must undergo the necessary industrial medicine tests before commencing work.

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Re: Surveillance of Exposure of Personnel to External Radiation

1. Surveillance of exposure of personnel to external radiation will be accomplished by means of special radiation-detection badges (hereinafter called TAG —Control of Radiation Exposure—badges). Technicians from the Radiation Safety Unit will decide whether a TAG badge is needed by a radiation worker, depending on the status of his or her work.

2. Personnel who have received TAG badges must wear them on an exposed part of their work clothing whenever they are in the work area.
3. The worker is responsible for preserving the badge—its loss involves the loss of all of its accumulated data, and its cost will be charged to the department.
4. Background badges have been placed in some of the work locations. Their objective is the continuous surveillance of radiation levels in that location. They must be kept in good order and must not be used for any other purpose.
6. ATTEMPTS TO CHECK THE BADGE BY EXPOSURE TO RADIATION ARE FORBIDDEN. DELIBERATE EXPOSURE OF THE BADGE TO RADIATION CONSTITUTES AN OFFENSE AGAINST STATE LAW AND WILL RESULT IN CANCELLATION OF THE RADIATION WORKER'S PERMIT.
7. Personnel who have stopped working with radiation, or have left University employ, must return their badges to the Radiation Safety Unit.
8. A radiation worker must inform the Radiation Safety Unit of any change in the status of his or her work (changes in materials, quantities, etc.).
9. Department/laboratory heads have the responsibility of informing the Radiation Safety Unit of any new radiation worker in the department.
10. TO ALL RADIATION PERSONNEL! YOUR CORD BADGE IS VALUELESS LYING IN A DRAWER OR ON A SHELF IN THE CORNER OF THE ROOM. FOR YOUR OWN SAFETY, ALWAYS WEAR YOUR BADGE WHEN YOU ARE IN THE WORK AREA.

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Re: The Cleaning of Radiation Laboratories

A **General**

1. Definition: for the purpose of this regulation, a radiation laboratory is any laboratory or other work area, the door to which bears a sign "DANGER – RADIOACTIVITY".
2. Every effort should be made to ensure that cleaners who are employed in a radiation laboratory should be permanent (in departments without their own cleaning staff, the contractor should be asked to avoid, as far as possible, changing the cleaning staff in radiation laboratories). In addition, care should be taken that the cleaners can read Hebrew.
3. Washing the floors and disposal of regular waste can be carried out by the cleaners without the presence of a laboratory technician/worker.

   DUSTING AND THE CLEANING OF WINDOWS IN A RADIATION LABORATORY MUST ONLY BE DONE UNDER THE SUPERVISION OF A LABORATORY WORKER.
4. The cleaning contractor must supply the cleaners with suitable protective equipment including: coats, work shoes, gloves and aprons.
5. In laboratories where there is a permanent cleaner, the cleaner can wash utensils. The washing of equipment that has come in contact with radioactive materials will be done in accordance with the procedures laid down in section C below.
6. Special cleaning activities and any departure from these regulations require prior approval of the Radiation Safety Unit.
7. THE LABORATORY WORKERS ARE RESPONSIBLE FOR INSTRUCTING CLEANERS AND SUPERVISING THEIR WORK IN ACCORDANCE WITH THESE REGULATIONS.
8. The head of the University Service Unit is responsible for communicating these regulations to contractors and for including the regulations in the internal work procedures that apply to supervision of cleaning.

B **THE CLEANING OF LABORATORIES IN WHICH WORK WITH RADIOACTIVE MATERIAL TAKES PLACE.**

1. All cleaners must wear lab coats, work shoes and gloves.
2. EACH LABORATORY SHALL HAVE ITS OWN SEPARATE WASH CLOTHS FOR EXCLUSIVE USE. THE USE OF THE SAME WASH CLOTHS FOR SEVERAL LABORATORIES AND OFFICES IS PROHIBITED.
3. CLEANERS SHALL ONLY TAKE REGULAR WASTE OUT OF THE LABORATORY.

   The bins that contain radioactive waste shall be clearly labelled and the cleaners must not touch them. (In special circumstances, the Radiation Safety Unit may give cleaners permission to remove radioactive waste. In such cases, the disposal shall take place under the supervision of a laboratory technician/worker.)

4. The cleaners must not touch laboratory equipment on the tables or on the floor.
5. The cleaners must not dispose of liquids—except the water used to clean the laboratory—down the drain.

C **THE WASHING OF EQUIPMENT THAT HAS COME IN CONTACT WITH RADIOACTIVE MATERIAL**

1. In special instances that a contractor's cleaners wash equipment that has come in contact with radioactive materials, the cleaners must obey the regulations for cleaning equipment (see the regulations immediately following in this safety handbook).
2. The washing of equipment that has come in contact with radioactive materials must be carried out only in a laboratory that has been approved for using radioactive materials.
3. Cleaners who wash equipment must wear a lab coat, work shoes, gloves and apron.
4. A laboratory worker/technician will instruct the cleaners and ensure that they carry out the instructions.

D **THE CLEANING OF LABORATORIES IN WHICH WORK WITH RADIATION EMITTING DEVICES OR RADIATION SOURCES TAKES PLACE.**

1. All laboratories in which radiation emitting devices are used have an illuminated sign outside the laboratory stating "DANGER RADIATION". When the sign is lit up, cleaning work must only be carried out in the presence of a laboratory worker who must be present in the laboratory during the operation of devices.
2. In such laboratories, when the sign is not lit up, cleaning (washing floors, waste disposal) can be unsupervised.
3. **IT IS FORBIDDEN TO TOUCH LABORATORY DEVICES OR EQUIPMENT**
4. In special laboratories to which there is no free access, (such as sub-critical units) **ALL CLEANING MUST BE DONE IN THE PRESENCE OF A LABORATORY WORKER.**

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Re: The Washing of Equipment that has Come in Contact with Radioactive Materials

Definition: **Any item of laboratory equipment that comes in contact with radioactive materials or contains a radioactive material in any quantity must be washed separately from all other laboratory equipment.**

1. The washing of equipment that has come in contact with radioactive materials will only be done in a laboratory that has been approved for radioactive work and by personnel authorised to use radioactive materials. In special cases, when the washing is carried out by a cleaner, the responsibility is that of the laboratory personnel. You must ensure that the cleaners work according to the regulations and use gloves, aprons, lab coats and work shoes.
2. The washing of utensils will only be carried out after liquid waste has been disposed of according to the regulations governing the handling of liquid radioactive waste, and only after the utensil has been checked to establish the level of contamination.
3. As far as possible, work with radioactive materials should be carried out using disposable utensils!! This is particularly important regarding all stages of work with large quantities of radioactive materials.
4. In the case of a utensil that has contained a significant amount of a radioactive material, even after the radioactive liquid has been disposed of in the appropriate way, the utensil still contains a significant amount of radioactive material, and therefore it must not be washed with the other utensils.
5. When the work involves radioactive materials for which the equipment can be checked by a radiation detector (P-32, Cr-51, Rb-86, I-125), the utensils must be checked before putting them in the wash. If the detector reveals a radiation level of more than three times the background level, the item must not be included in regular radioactive washing.
6. For materials where this is not possible (H-3, C-14, S-35, Ca-45), a smear test with a liquid luminescence detector can be performed.. When a smear test is not performed, then all the utensils that contained substantial amounts of radioactive materials (more than 10 μCi) must be treated as highly contaminated.
7. In the case of radioactive materials with a short half-life, it is possible to leave the utensils long enough for the materials to disintegrate, rather than washing them. In co-operation with the Radiation Safety Unit, a separate and closed place in the laboratory , suitably labelled, can be set up for such items.
8. When it impossible to dispose of the equipment or to leave it for disintegration to take place, it must be cleaned separately from the rest of the equipment. Cleaning will be carried out without pouring the cleaning liquid down the drain, but into the special containers established for the disposal of radioactive liquids. Such cleaning must only be performed in the laboratory , and by laboratory personnel authorised to use radioactive materials.

9. Utensils that have low-level contamination (after they have been checked) must be immersed in a bath full of water for at least 24 hours. The water in the bath must be changed during the immersion. The bath must be clearly labelled.
10. It is highly advisable to use a bath specially designed for the washing of utensils. In any event, you must ensure that the water pipe to the bath is securely fixed and is not itself immersed in the water. Ensure that there is no leakage of water from the bath. The water will be disposed of into the regular drain.
11. After the immersion period, the utensils can be washed in a regular manner. However, equipment that has come in contact with radioactive materials must be washed separately.

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Re: Radiation Safety Placards

A. **Laboratory Placards**

1, The University has official standard placards to identify laboratories. The sign is 25 x 17 cm in size, and has red lettering on a yellow background (see appendix).

2. A placard must be affixed to all entrances to a radiation laboratory, as well as inside the laboratory and at all locations where radioactive materials are stored.

3. The placard must specify the level of danger in the laboratory: radioactive materials/radiation sources/radiation emitting equipment. The placard will also give the name of the person in charge of the laboratory, his or her telephone number, and how to contact the Radiation Safety Unit.

4. If a placard is missing or not up-to-date, inform the Radiation Safety Unit.

B. **Labelling equipment and storage areas**

1. A standard sticker has been prepared by the University for equipment and storage areas. The sticker is 7 x 1.5 cm in size, and has red lettering on a yellow background. The University also has internationally accepted marking tapes (see appendix).

2. All equipment that comes in contact with radioactive materials must be clearly and prominently labelled, as must locations where work is performed or radioactive materials (including waste) are stored.

3. Stickers and marking tapes can be obtained from the Radiation Safety Unit.

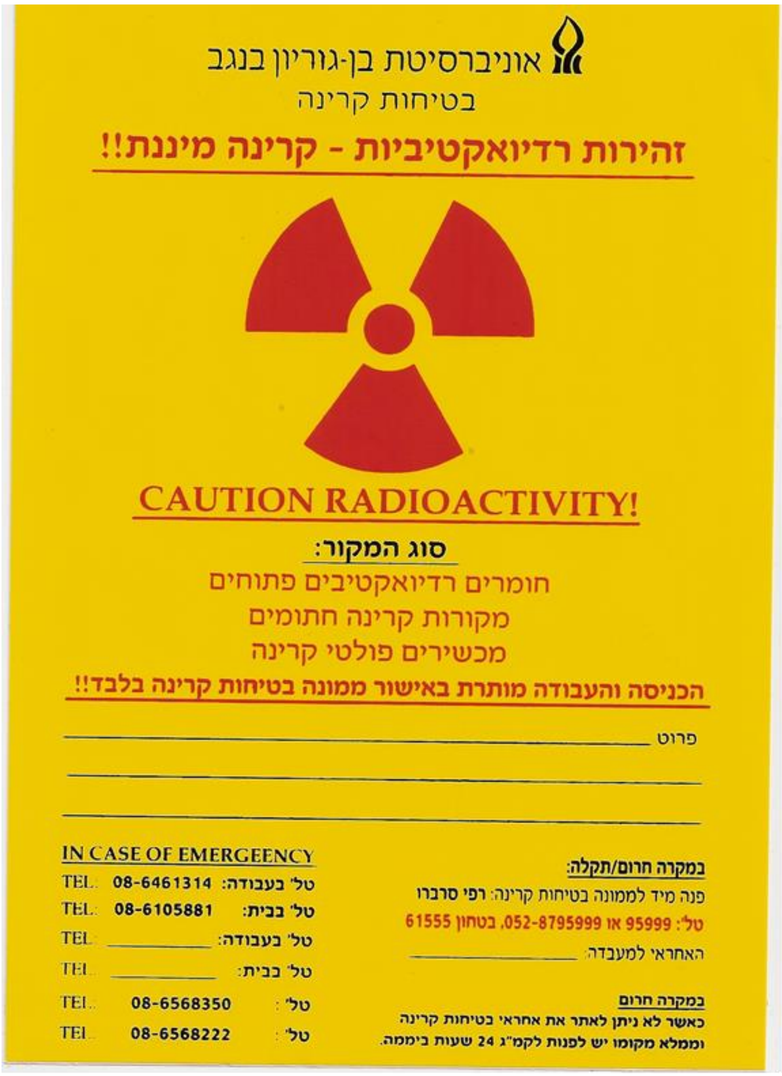
C. **Special Placards**

1. In special cases: mishaps, the spilling of a radioactive material, the danger of exposure, etc., special signs will be displayed. YOU MUST OBEY THE REGULATIONS REGARDING SIGNS!

   Attention!! The arrangement of radiation safety placards and signs will only be carried out by the Radiation Safety Unit personnel. The placing or removal of radiation safety placards without permission is prohibited !

Radiation Safety Unit

Example of placard



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Information Sheet and Regulations for Working with Tritium (H-3)

Physical half-life	12.4 years
Effective half-life	10 days
Type of radiation	Beta β
Radiation energy	18.6 KeV maximum, 5.6 KeV average
Danger level	Low
Maximum activity	10 mCi

Working Regulations

1. Work will only be performed by personnel and in laboratories authorised to use tritium. The regular permit only applies to using the material in liquid form. All work with volatile or gaseous radioactive materials (or where there is a possibility of the escape of gas during an experiment), requires a special permit from the Radiation Safety Unit.
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. Work with the “mother solution” (high concentration) must be performed in a fume hood.
4. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
5. It is advisable to use as small a quantity of a radioactive material as possible.
6. Personnel must wear lab coats, closed shoes and gloves throughout the period of work with the material.
7. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
8. Personnel must check themselves and the work area as frequently as possible with a suitable detector. In particular, before leaving the laboratory and at the end of the workday. In the case of work involving tritium, it is impossible to use regular radiation detectors. The check must be performed by a “smear” test. The area to be tested is swabbed by a piece of moist paper that is then inserted into a vial containing a scintillating liquid, and a radiation count is performed in a detector suited to the specific material. At the same time, a count is performed on a piece of clean paper to establish the background level. Any result substantially different than the background must be immediately reported to the Radiation Safety Unit. Before use of a radioactive material, the worker must learn how to operate the scintillation detector, even if the device is not to be used in the experiments.
9. In using tritium there is a problem of the penetration of tritium through the gloves by a process of isotopic exchange. To overcome the problem it is recommended that you wear two pairs of gloves and change them as frequently as possible (every half-an-hour).

10. Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room. Liquid radioactive waste must not be poured down the drain!!
11. All equipment that comes in contact with radioactive materials must be labelled with a “radioactive” s ticker, and the work area must be suitably placarded.
12. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.
13. DNA compounds labelled by tritium, such as thymedine, are more dangerous than water compounds labelled with tritium. It is therefore advisable to use as small a quantity of such DNA compounds as possible, and to take every precaution to prevent them from penetrating the body.
14. You must know the radioactive and chemical properties of any material or compound before starting to use it.
15. The follow-up of internal exposure to/absorption of radioactive materials is performed by means of urine tests. Urine samples must be supplied as requested by the Radiation Safety Unit.

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Information Sheet and Regulations for Working with Sulphur (S-35)

Physical half-life	87.4 days
Effective half-life	44.3 days
Type of radiation	Beta β
Radiation energy	167 KeV maximum, 49 KeV average
Risk level	Medium
Maximum activity	0.1 mCi

Working Regulations

1. Work will only be performed by personnel and in laboratories authorised to use S-35. The regular permit only applies to use of the material in liquid form. All work with volatile or gaseous radioactive materials (or where there is a possibility of the escape of gas during an experiment), requires a special permit from the Radiation Safety Unit. Work with amino acids labelled with S-35, such as Cysteine or Methionine requires a special permit from the Radiation Safety Unit (see below).
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. Work with the “mother solution” (high concentration) must be performed in a fume hood.
4. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
5. It is advisable to use as small a quantity of a radioactive material as possible.
6. Personnel must wear lab coats, closed shoes and gloves throughout the period of work with the material.
7. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
8. Personnel must check themselves and the work area as frequently as possible with a suitable detector. In particular, before leaving the laboratory and at the end of the workday. In the case of work involving S-35, it is impossible to use regular radiation detectors. The check must be performed by a “smear” test. The area to be tested is swabbed by a piece of moist paper that is then inserted into a vial containing a scintillating liquid, and a radiation count is performed in a detector suited to the specific material. At the same time, a count is performed on a piece of clean paper to establish the background level. Any result substantially different than the background must be immediately reported to the Radiation Safety Unit. Before use of a radioactive material, the worker must learn how to operate the scintillating detector, even if the device is not to be used in the experiments.

9. Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room. Liquid radioactive waste must not be poured down the drain!!
10. All equipment that comes in contact with radioactive materials must be labelled with a “radioactive” sticker, and the work area must be suitably placarded.
11. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.
12. You must know the radioactive and chemical properties of any material or compound before starting to use it.
13. The follow-up of internal exposure to/absorption of radioactive materials is performed by means of urine tests. Urine samples must be supplied as requested by the Radiation Safety Unit.

USING CYSTEINE AND METHIONINE

In addition to the work procedures detailed above, using amino acids labelled with S-35 requires special means due to the formation of volatile radioactive by-products during the radioactive disintegration of the material, especially during freezing, defrosting, incubating and storage of waste. These days, it is estimated that each week about 0.01% of the material disintegrates. In practice this means that from a stock of 5 mCi , we can expect the formation of some 0.5 μCi of volatile by-products per week. We must therefore follow the procedures necessary to prevent this material both from entering the body by inhalation, and contaminating the environment.

1. The use of amino acids labelled with S-35, such as Cysteine or Methionine requires a special permit from the Radiation Safety Unit. The permit will only be issued if the laboratory meets the standards laid down by the Radiation Safety Unit.
2. Most of the work must be performed in a functioning fume hood.
3. ALL WORK WITH STOCKS OF THE RADIOACTIVE MATERIAL MUST BE PERFORMED IN A FUME HOOD.
4. Freezing of the radioactive material must be carried out in a sealed container.
5. Activities such as heating, agitation, etc., must be carried out in sealed containers and a fume hood.
6. THE DEFROSTING OF A FROZEN FLASK OR BOTTLE CONTAINING S-35 MUST BE DONE IN A FUME HOOD. BEFORE STARTING THE DEFROSTING, A SYRINGE WITH COTTON WOOL AT ITS END AND FILLED WITH ACTIVE CARBON MUST BE PREPARED. INSERT THE NEEDLE OF THE SYRINGE INTO THE FLASK WITHOUT THE NEEDLE TOUCHING THE FROZEN LIQUID. IN THIS STATE RAPIDLY PERFORM THE DEFROSTING OF THE FLASK. AFTER DEFROSTING, THE SYRINGE MUST BE REMOVED AND DISPOSED OF IN THE RADIOACTIVE WASTE BIN.
7. Incubation must be done in a sealed container. After incubation, the container must be opened in a fume hood. Special equipment, designed for work with volatile materials, can be obtained.
8. When it is impossible to perform freezing or incubation in a sealed container, procedures to ensure the absorption of the volatile by-products. must be followed The utensils can be wrapped in paper made with active carbon, or can be placed in a double container filled with active carbon.

9. Wastes must be stored in the laboratory for as short a period as possible, in the fume hood and in a sealed container.

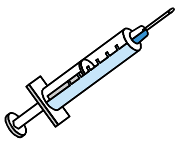
10. IN ORDER TO ENSURE THAT RADIOACTIVE CONTAMINATION IS NOT SPREAD, CHECKS MUST BE PERFORMED AT EVERY STAGE OF THE WORK AND PARTICULARLY BEFORE LEAVING THE LABORATORY. THIS APPLIES TO EVERY PART OF THE WORK AREA, ESPECIALLY THOSE AREAS WHERE DEFROSTING, INCUBATION, AGITATION, ETC. WERE CARRIED OUT. A "SMEAR" TEST MUST BE PERFORMED AND THE WATER IN THE INCUBATOR MUST BE CHECKED.

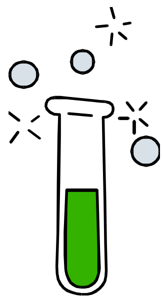
Radiation Safety Unit

CAUTION: HANDLING INSTRUCTIONS: Small amounts of volatile ^{35}S - labeled decomposition products may by generated especially at elevated temperatures therefore we recommend that prior to opening, vials are first vented in a fume hood using the following procedure:

1. Slide aside the dust cover on the cap to expose the septum.
2. Pierce the septum with a cotton-plugged syringe needle or charcoal trap (NEN™ NEX-033T), taking care that the tip does not come in contact with the frozen product.
3. If the product is frozen, quick-thaw at room temperature or in a 37°C water bath. Any pressure developed will vent through the syringe needle.
4. Remove the needle and dispose of as contaminated equipment.

When used for cell labeling, we recommend that specific steps be taken to minimize incubator and water bath contamination. We suggest using a shallow tray of activated charcoal, charcoal sticks or charcoal filter units to trap ^{35}S-volatiles and reduce contamination.





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Information Sheet and Regulations for Working with Carbon 14 (C-14)

Physical half-life	5730 years
Effective half-life	10 days
Type of radiation	Beta β
Radiation energy	156 KeV maximum, 49 KeV average
Risk level	Medium
Maximum activity	0.1 mCi

Working Regulations

1. Work will only be performed by personnel and in laboratories authorised to use C-14 The regular permit only applies to work with the material in liquid form. All work with volatile or gaseous radioactive materials (or where there is a possibility of the escape of gas during an experiment), requires a special permit from the Radiation Safety Unit.
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. Work with the “mother solution” (high concentration) must be performed in a fume hood.
4. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
5. It is advisable to use as small a quantity of a radioactive material as possible.
6. Personnel must wear lab coats, closed shoes and gloves throughout the period of work with the material.
7. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
8. Personnel must check themselves and the work area as frequently as possible with a suitable detector. In particular, before leaving the laboratory and at the end of the workday. In the case of work involving C14, it is impossible to use regular radiation detectors. The check must be performed by a “smear” test. The area to be tested is swabbed by a piece of moist paper that is then inserted into a vial containing a scintillating liquid, and a radiation count is performed in a detector suited to the specific material. At the same time, a count is performed on a piece of clean paper to establish the background level. Any result substantially different than the background must be immediately reported to the Radiation Safety Unit. Before use of a radioactive material, the worker must learn how to operate the scintillating detector, even if the device is not to be used in the experiments.
9. In using C-14 there is a problem of penetration through the gloves by a process of isotopic exchange. To overcome the problem it is recommended that you wear two pairs of gloves and change them as frequently as possible (every

half-an-hour). This is particularly important in work with acids of halogens that are labelled with C-14.

10. Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room. Liquid radioactive waste must not be poured down the drain!!
11. All equipment that comes in contact with radioactive materials must be labelled with a “radioactive” sticker, and the work area must be suitably labelled.
12. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.
13. You must know the radioactive and chemical properties of any material or compound before starting to use it.
14. The follow-up of internal exposure to/absorption of radioactive materials is performed by means of urine tests. Urine samples must be supplied as requested by the Radiation Safety Unit.
15. If, during the course of the work, there is the possibility of the release of CO_2 labelled with C-14, you must use a fume hood, and as far as possible, in a closed system. Steps must be taken to absorb the gas and prevent its release to the atmosphere. In any event, such experiments require a special permit from the Radiation Safety Unit.

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Information Sheet and Regulations for Working with Phosphor (P-32)

Physical half-life	14.3 days
Effective half-life	13.5 days
Type of radiation	Beta β
Radiation energy	1.71 MeV maximum, 0.69 MeV average
Risk level	Medium
Maximum activity	0.1 mCi

THE STRENGTH OF RADIATION EMANATING FROM THE OPENING OF A FLASK OR BOTTLE CONTAINING 1 mCi IS 26 R/HOUR. THIS IS VERY HIGH AND MERITS ATTENTION TO THE DANGER OF EXPOSURE TO EXTERNAL RADIATION

Maximum range	through air – 6 meters	in water – 8 mm.
Required shielding	Working with quantities of up to 1 mCi, Perspex of about 12 mm. in thickness can be used. For larger quantities, a lead sheet of at least 3 mm. should be added.	

General: in addition to the danger of internal exposure to radiation (as a result of the penetration of the body by radioactive material), there is a danger of external exposure. The long range of the radiation through the air and the high level of its energy require measures to reduce external exposure. Strict attention to the safety regulations will avoid unnecessary exposure.

Work Procedures

1. Work will only be performed by personnel and in laboratories authorised to use P-32. The regular permit only applies to use of the material in liquid form. All work with volatile or gaseous radioactive materials (or where there is a possibility of the escape of gas during an experiment), requires a special permit from the Radiation Safety Unit.
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
4. It is advisable to use as small a quantity of a radioactive material as possible.
5. Personnel must wear lab coats, closed shoes and gloves throughout the period of work with the material. The gloves must be checked and changed as often as possible.
6. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
7. Personnel must check themselves and the work area as frequently as possible with a suitable detector. In particular, before leaving the laboratory and at the end of the workday. In work with P-32, tests should be carried out with a suitable detector (Geiger counter). The device must be at hand throughout the work. Gloves, equipment, clothes, the floor and the work area must all be checked. Where necessary, “smear” tests should also be performed.

8 Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room. Liquid radioactive waste must not be poured down the drain!! Both solid and liquid waste from P-32 are significant sources of radiation because most of the radioactive material becomes waste. Waste must not be accumulated in the laboratory. Both solid and liquid waste must be placed inside suitable Perspex shielding.

9. All equipment that comes in contact with radioactive materials must be labelled with a “radioactive” sticker, and the work area must be suitably labelled.

10. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.

11. You must know the radioactive and chemical properties of any material or compound before starting to use it.

12. The follow-up of internal exposure to/absorption of radioactive materials is performed by means of urine tests. Urine samples must be supplied as requested by the Radiation Safety Unit.

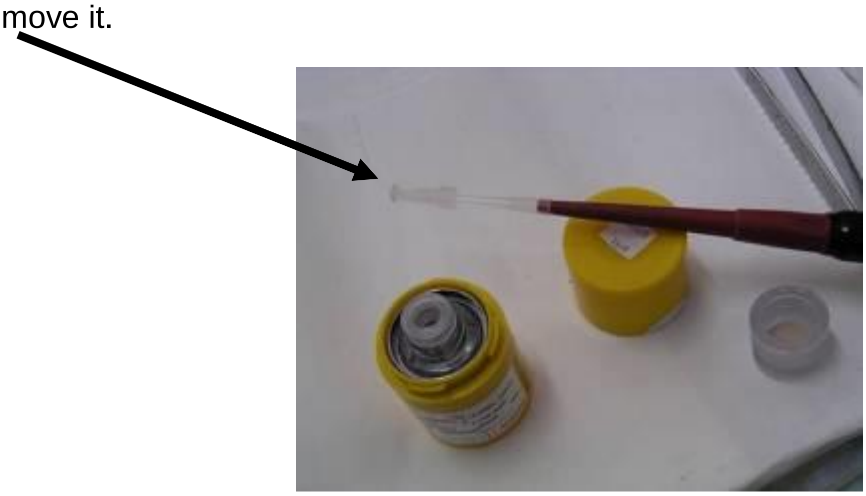
13 Work with the “mother solution” (high concentration) must be performed in a fume hood and behind Perspex shielding. The flask or bottle containing the mother solution must remain inside a lead pot. You must not use an exposed flask. You must not work over an open flask that contains material of high concentration. The initial opening of a flask containing material of high concentration must be done with great care. Remember that the inner surface of the cork/cap is highly contaminated.

Even when using small quantities of P-32, Perspex shielding is mandatory.

14. When taking out the flask or bottle containing the stock of radioactive material is unavoidable , laboratory tongs must be used (the flask must not be hand held) together with suitable Perspex shielding. Take as short a time to transfer the flask as possible.

15. Some of the suppliers of P-32 have designed the lid of the lead pot to open the cap of the flask with no exposure of the hands (NEN Ltd. for example). Other companies use a Perspex cap to reduce the amount of radiation.

16. The taking up of liquids from a flask or bottle containing the stock of radioactive material must only be performed with an automatic pipette and not with a syringe or any other method that must be held close to the radioactive material.
17. Washing of utensils will be carried out in accordance with the regulations for washing utensils. In any event, you must check any utensil before washing it. Contaminated utensils must not be washed in the sink. Any utensil that was tested by a detection device and gave a result above the background level must be immersed in cleaning fluid (which must then be disposed of via the radioactive waste).
18. When experimenting with P-32 in quantities above 0.5 mCi, personnel will wear a badge for surveillance of external exposure to radiation.
19. When you buy p-32 from Amersham that is supplied at room temperature a spill guard is inserted inside the vial. The first user must remove it to the solid radioactive waste .This must be done very carefully and only by experience workers. Prepare a pipette with a tip, insert the tip into the spill guard and remove it.



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Information Sheet and Regulations for Working with Calcium (Ca-45)

Physical half-life	165 days
Effective half-life	162 days
Type of radiation	Beta β
Radiation energy	1252 KeV maximum, 75 KeV average
Risk level	High
Maximum activity	100 μCi

Work Procedures

1. Work will only be performed by personnel and in laboratories authorised to use materials containing Ca-45.
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. Work with the “mother solution” (high concentration) must be performed in a fume hood.
4. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
5. It is advisable to use as small a quantity of a radioactive material as possible.
6. Ca-45 is considered a highly dangerous material due to the fear of internal exposure. It is extremely important to follow all the safety procedures strictly, in particular to check the work area and the workers themselves for signs of contamination. There is no danger of external exposure to radiation.
7. Personnel must wear lab coats, closed shoes and gloves throughout the period of work with the material.
8. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
9. Personnel must check themselves and the work area as frequently as possible with a suitable detector. In particular, before leaving the laboratory and at the end of the workday. In the case of work involving Ca-45, it is impossible to use regular radiation detectors. The check must be performed by a “smear” test. The area to be tested is swabbed by a piece of moist paper that is then inserted into a vial containing a scintillating liquid, and a radiation count is performed in a detector suited to the specific material. At the same time, a count is performed on a piece of clean paper to establish the background level. Any result substantially different than the background must be immediately reported to the Radiation Safety Unit.
10. Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room.
11. All equipment that comes in contact with radioactive materials must be labelled with a “radioactive” sticker, and the work area must be suitably placarded.
12. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.

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Information Sheet and Regulations
for Working with Chromium(Cr-51)

Physical half-life	27.7days	Effective half-life	26.4 days
Type of radiation	Gamma γ		
Radiation energy	γ – 0.32 MeV		
Strength of radiation from contact	with an exposed	source of 1 MCi	160Mr/Hr
Risk level	Medium to Low		
Half-thickness of lead	1.6 mm approx.		
Maximum activity	1 MCi		

Work Procedures

1. Work will only be performed by personnel and in laboratories authorised to use materials containing Cr-51.
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. Personnel must wear radiation badges throughout their work in the laboratory.
4. WORK WITH THE "MOTHER SOLUTION" (HIGH CONCENTRATION) MUST BE PERFORMED IN A FUME HOOD, WITH THE BOTTLE OR FLASK CONTAINING THE MOTHER SOLUTION ALWAYS BEING KEPT IN ITS LEAD POT. REMOVAL OF THE FLASK FROM ITS LEAD POT WITHOUT SPECIAL SHIELDING IS FORBIDDEN.
5. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
6. It is advisable to use as small a quantity of a radioactive material as possible.
7. Personnel must wear lab coats, closed shoes and gloves throughout the period of work
8. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
9. DURING LABORATORY WORK AN APPROPRIATE RADIATION DETECTOR MUST ALWAYS BE AVAILABLE. PERSONNEL MUST CHECK THEMSELVES AND THE WORK AREA AS FREQUENTLY AS POSSIBLE, AND IN PARTICULAR, BEFORE LEAVING THE LABORATORY AND AT THE END OF THE WORKDAY.
10. Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room.
11. All equipment that comes in contact with radioactive materials must be labelled with a "radioactive" sticker, and the work area must be suitably placarded.
12. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.

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Information Sheet and Regulations for Working with Rubidium(Rb-86)

Physical half-life	18.66days	Effective half-life	13.2 days
Type of radiation	β, γ		
Radiation energy	β - 1.78 MeV γ - 1.07 MeV		
Strength of radiation from contact with an exposed source of 1 MCi	500 Mr/Hr		
Risk level	Medium		
Half-thickness of lead	9 mm approx.		
Maximum activity	1 MCi		

Work Procedures

1. Work will only be performed by personnel and in laboratories authorised to use materials containing Rb-86.
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. Personnel must wear radiation badges throughout their work in the laboratory.
4. WORK WITH THE "MOTHER SOLUTION" (HIGH CONCENTRATION) MUST BE PERFORMED IN A FUME HOOD, WITH THE BOTTLE OR FLASK CONTAINING THE MOTHER SOLUTION ALWAYS BEING KEPT IN ITS LEAD POT. REMOVAL OF THE FLASK FROM ITS LEAD POT WITHOUT SPECIAL SHIELDING IS FORBIDDEN.
5. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
6. It is advisable to use as small a quantity of a radioactive material as possible.
7. Personnel must wear lab coats, closed shoes and gloves throughout the period of work
8. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
9. DURING LABORATORY WORK AN APPROPRIATE RADIATION DETECTOR MUST ALWAYS BE AVAILABLE. PERSONNEL MUST CHECK THEMSELVES AND THE WORK AREA AS FREQUENTLY AS POSSIBLE, AND IN PARTICULAR, BEFORE LEAVING THE LABORATORY AND AT THE END OF THE WORKDAY.
10. Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room.
11. All equipment that comes in contact with radioactive materials must be labelled with a "radioactive" sticker, and the work area must be suitably labelled.
12. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.

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Information Sheet and Regulations for Working with Iodine(I-125)

Physical half-life	60.2 days
Effective half-life	41.8 days
Type of radiation	γ, X
Radiation energy	27-35 Kev
Risk level	High
Maximum activity	100 μCi

Work Procedures

1. Work will only be performed by personnel and in laboratories authorised to use materials containing I-125.
2. The work will be performed according to all the safety regulations applying to radiation as published in the Ben-Gurion University Radiation Safety Handbook.
3. A liquid radioactive material must always be transported from room to room or inside a room in a tray lined with absorbent material.
4. It is advisable to use as small a quantity of a radioactive material as possible.
5. Personnel must wear lab coats, closed shoes and gloves throughout the period of work
6. Eating, drinking and smoking in the laboratory are prohibited! The use of the mouth to take up liquids (by pipette, etc.) is prohibited. Special means must be adopted to take up liquids.
7. Personnel must check themselves and the work area as frequently as possible with a suitable detector. In particular, before leaving the laboratory and at the end of the workday. In the case of work involving I-125, it is impossible to use regular radiation detectors and we must either use special detectors or perform a "smear" test. The area to be tested is swabbed by a piece of moist paper that is then inserted into a vial, and a radiation count is performed in a detector (a Gamma Counter) suited to the specific material. At the same time, a count is performed on a piece of clean paper to establish the background level. Any result substantially different than the background must be immediately reported to the Radiation Safety Unit.
8. Waste must not be accumulated in the laboratory. At the end of an experiment or a work day, waste must be taken to a waste room.
9. All equipment that comes in contact with radioactive materials must be labelled with a "radioactive" sticker, and the work area must be suitably labelled.
10. Any mishap or suspicion of mishap must be reported immediately to the Radiation Safety Unit.
11. **THE MAXIMUM QUANTITY OF I-125 THAT SHOULD BE USED IN A RADIATION LABORATORY IS 100 μCI, ON CONDITION THAT NO WORK IS PERFORMED WITH FREE IODINE. WORK WITH FREE IODINE WILL ONLY BE PERFORMED IN SPECIAL LABORATORIES THAT HAVE BEEN APPROVED BY THE RADIATION SAFETY UNIT.**

12. I-125 is classified as a very dangerous material due to its highly volatile nature, and the risk of internal exposure resulting from inhalation. At the same time there is a risk of external exposure, and therefore precautions must be taken to reduce exposure to a minimum.
13. I-125 must be stored in a lead pot of at least 3mm. thickness. It is advisable to use lead “blankets” as protection when working with smaller quantities.
14. **IT IS ADVISABLE TO PERFORM ALL WORK WITH I-125 IN A FUME HOOD. IN ANY EVENT, A FLASK OR BOTTLE CONTAINING I-125 MUST BE OPENED IN A FUME HOOD, AS WELL AS WORK WITH ANY QUANTITY ABOVE 10 μCI.**
15. When the quantity of I-125 does not exceed 10 μCi and does not include free iodine, and when it is impossible to use a fume hood, it is possible to work on laboratory tables. Even in such cases, however, bottles must only be opened in a fume hood.
16. Solutions containing ions of iodine must not be converted to acids nor must they be stored in a frozen state. Both cases lead to increased volatility.
17. Certain iodine compounds can penetrate through regular rubber gloves. Therefore, in an case when this is suspected, you must wear two pairs of gloves, or wear plastic gloves over the rubber ones. The outer pair of gloves should be changed as often as possible.
18. In any case of suspicion of internal exposure to iodine, you must inform the Radiation Safety Unit immediately. This is particularly important since even in such a case it is possible to reduce the amount of radioactive iodine the body will absorb by introducing a quantity of non-radioactive iodine to the body.
19. Wherever radioactive iodine is used, you must keep an alkaline solution of sodium thiosulphide at hand. In the event of the spread of contamination, the area must be treated with the above solution before cleaning.

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Ten Golden Rules

1. Understand the nature of the hazard and get practical training

Never work with unprotected cuts or breaks in the skin, particularly on the hands or forearms. Never use any mouth operated equipment in any area where unsealed radioactive material is used. Always store compounds under the conditions recommended. Label all containers clearly indicating nuclide, compound, specific activity, total activity, date and name of user. Containers should be properly sealed.

2. Plan ahead to minimize time spent handling radioactivity

Carry out a dummy run without radioactivity to check your procedures. The shorter the time the smaller the dose.

3. Distance yourself appropriately from sources of radiation

Doubling the distance from the source quarters the radiation dose (Inverse Square Law).

4. Use appropriate shielding for the radiation

1 cm Perspex (Plexiglas) will stop all beta particles but beware "Bremsstrahlung" from high energy beta emitters. Use lead acylic or a suitable thickness of lead for X and gamma emitters.

5. Contain radioactive materials in defined work areas

Always keep active and inactive work separated as far as possible, preferably maintaining rooms used solely for radioactive work. Always work over a spill tray and work in a ventilated enclosure. These rules may be relaxed for small (a few tens of kBq) quantities of ^{3}H, ^{35}S, ^{14}C and ^{125}I compounds in a non-volatile form in solution.

6. Wear appropriate protective clothing and dosimeters

Laboratory overalls, safety glasses and surgical gloves must be worn at all times. However, beware of static charge on gloves when handling fine powders. Local rules will define what dosimeters should be worn: for example, body film badge, thermoluminescent extremity dosimeter for work with high energy beta emitters etc.

7. Monitor the work area frequently for contamination control

In the event of a spill - follow the prepared contingency plan:

i) verbally warn all people in the vicinity
ii) restrict unnecessary movement into and through the area
iii) report the spill to the Radiation Protection Supervisor/Adviser
iv) treat contaminated personnel first
v) follow clean-up protocol

8. Follow the local rules and safe ways of working

Do not eat, drink, smoke or apply cosmetics in an area where unsealed radioactive substances are handled. Use paper handkerchiefs and dispose of them appropriately. Never pipette radioactive solution by mouth. Always work carefully and tidily.

9. Minimize accumulation of waste and dispose of it by appropriate routes

Use the minimum quantity of radioactivity needed for the investigation. Disposal of all radioactive waste is subject to statutory control. Be aware of the requirements and use only authorized routes of disposal.

10. After completion of work - monitor yourself, wash and monitor again

NEVER FORGET TO DO THIS. Report to the local supervisor if contamination is found.

amersham pharmacia biotech

NOTIFICATION TO THE RADIATION SAFETY UNIT

IN EVERY CASE OF MISHAP OR SUSPICION OF MISHAP THE RADIATION SAFETY UNIT MUST BE IMMEDIATELY INFORMED.

. Head of the Radiation Safety Unit:
Michal Baram, Telephone at work:

(08) 6461314 (61314)

Mobile 0528795999

95999 from inside the university.

61555 the security department.

Assistant Head: Anatoliy Rodnianskiy,
Telephone at work: (08) 6472489
at home 0547256824

TO: THE RADIATION SAFETY UNIT, DEPARTMENT OF NUCLEAR ENGINEERING

Name: _______________ Father's Name: _____________ I.D. No.: ____________

Male/Female , Pregnant y/n , Head of Lab:_________________ Citizenship:_____
Kopat Holim___________ email ______________________________
Year of Birth: ________ Dept.: ____________ Lab.: ___________ Work Tel.: _______

I INTEND TO PERFORM RADIATION WORK WITH THE FOLLOWING MATERIALS:

COMPLETE THE DETAILS ACCORDING TO TYPE OF ACTIVITY WITH RADIATION

1. DETAILS OF RADIOACTIVE MATERIALS: Type of materials: _________________
   General Activity in Laboratory (in storage): ___________
   Activity in Experiment:____________________________
   Short Description of Use of Radioactive Material: ___________________________
   ____
   ____

2. DETAILS OF RADIATION SOURCES: Types of Source, Activity level of Each source, and Short Description of the Usage.
   ____
   ____

3. RADIATION EMITTING DEVICE: Type of Device:

   Manufacturer: _________________ Work Voltage _______ Current ___________

   Description of Use: ____

<u>DECLARATION</u>: I HAVE CAREFULLY READ THE WORK PROCEDURES AND REGULATIONS PERTAINING TO RADIOACTIVE MATERIALS, RADIATION SOURCES, AND RADIATION-EMITTING DEVICES. I WILL WORK ACCORDING TO THE PROCEDURES AND REGULATIONS AND I AM AWARE THAT BREAKING THE REGULATIONS WILL LEAD TO CANCELLATION OF MY PERMIT TO WORK WITH RADIATION. I AM AWARE THAT IF I DON'T UNDERSTAND THE SAFETY PROCDURES OR UNABLE TO WORK ACORDING THE SAFETY PROCDURES, I MUST NOTIFY RADITION SAFETY. I AM AWARE THAT I MUST NOT START WORK WITH RADIATION BEFORE I RECEIVE MY PERMIT FROM THE RADIATION SAFETY UNIT,THE HEAD OF THE LAB AND OCCUPATIONAL CLINIC.

Name: _______________ Signature: ___________________ Date: _____________

PLEASE DETACH THIS PAGE AND SEND IT TO THE RADIATION SAFETY UNIT

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