Safety when working with radioactive compounds

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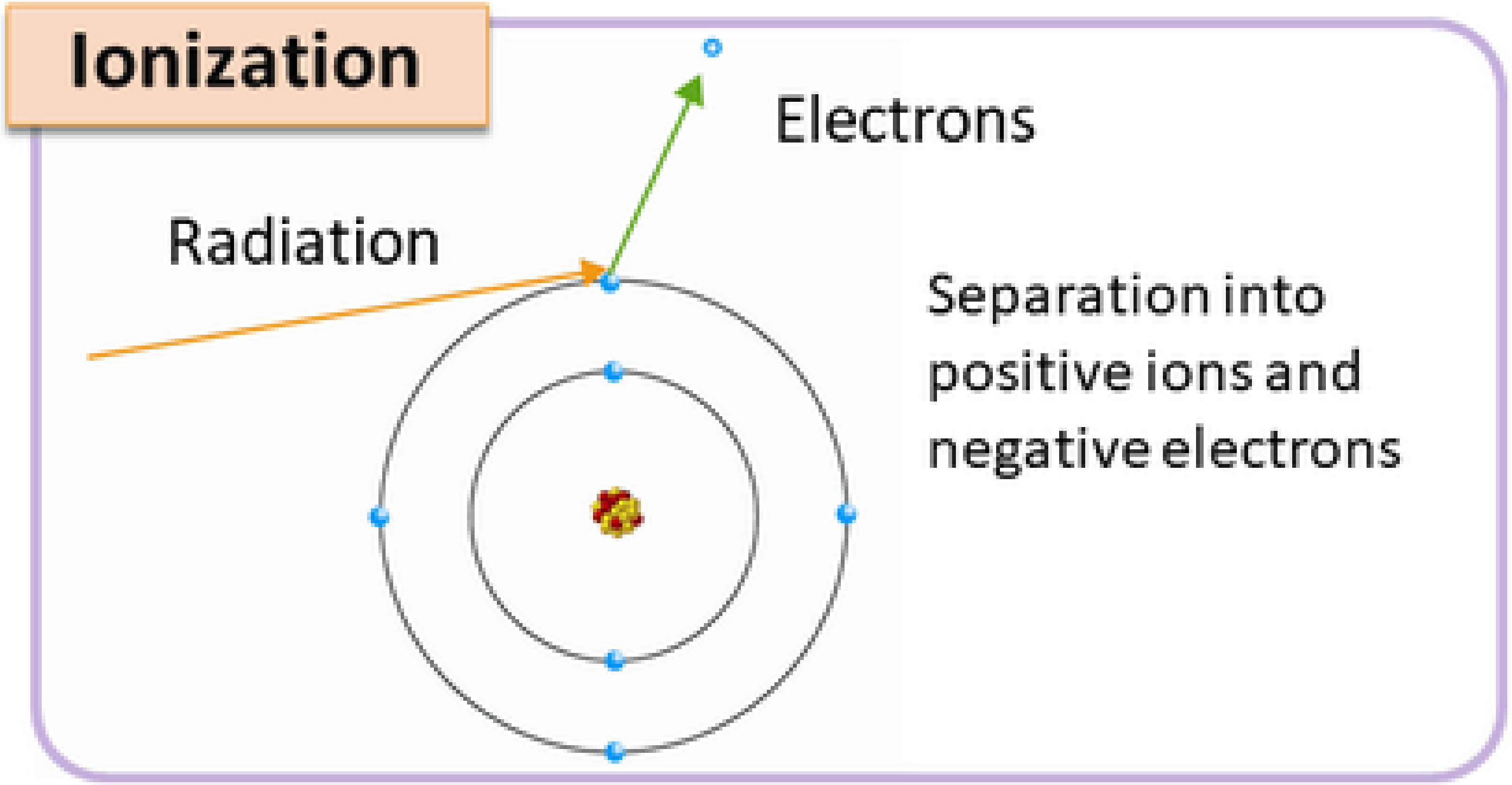
Ionizing radiation

- Particle radiation (alpha or beta radiation)
- **Alpha radiation** = helium nuclei emission
- **Beta radiation** = electron emission

- Electromagnetic radiation (**gamma radiation**)

- The energy level of the radiation is varying dependent on the isotope
- Higher energy = higher risc

Ionizing radiation



Particle radiation: β radiation of P-32

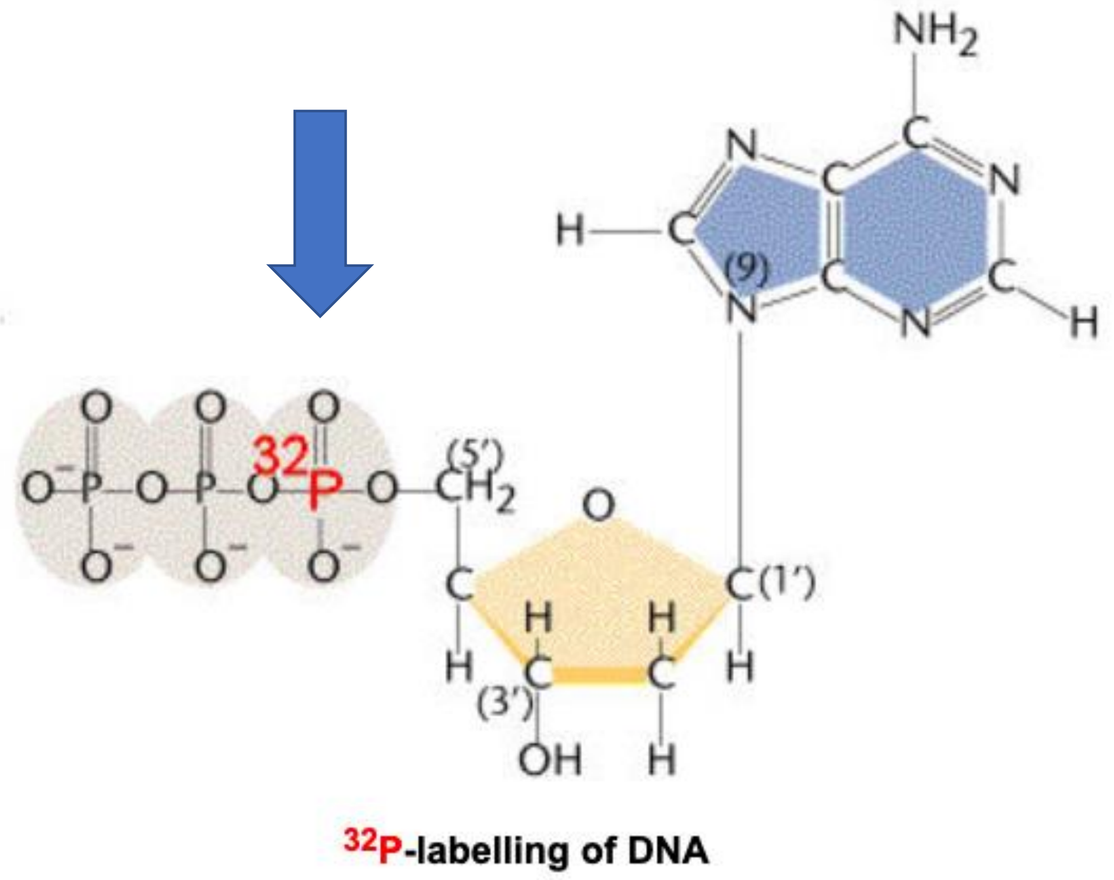
$$^{1}_{0}n \longrightarrow {}_{0}\beta^{-} + {}^{1}_{1}P$$

Mass is the same

$$^{32}_{15}P \longrightarrow {}_{0}\beta^{-} + {}^{32}_{16}S$$

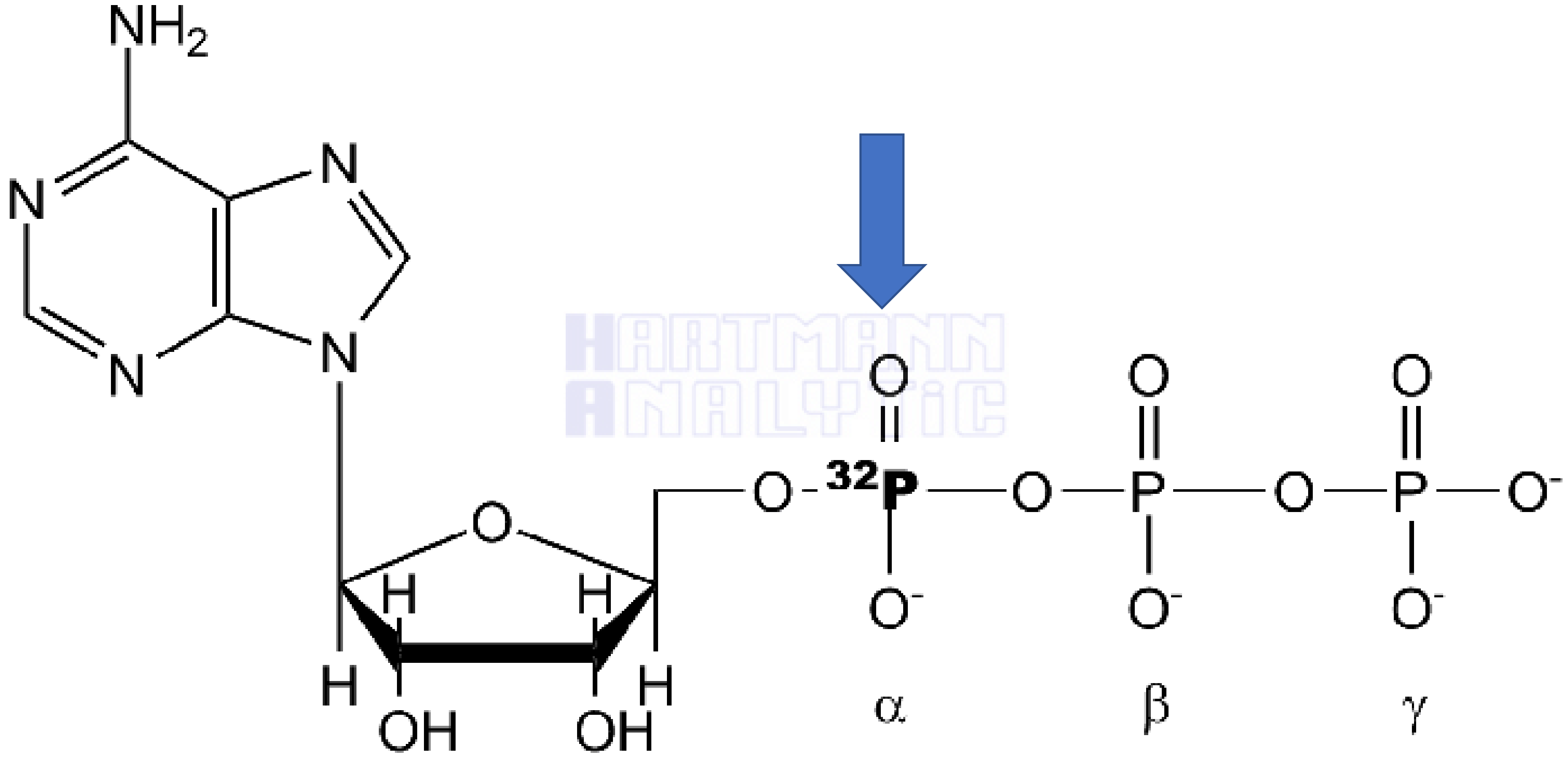
Proton number is increased

In β radiation the mass is the same, but an extra proton
is formed together with emission of an electron (β radiation).



[alpha-P32]dATP

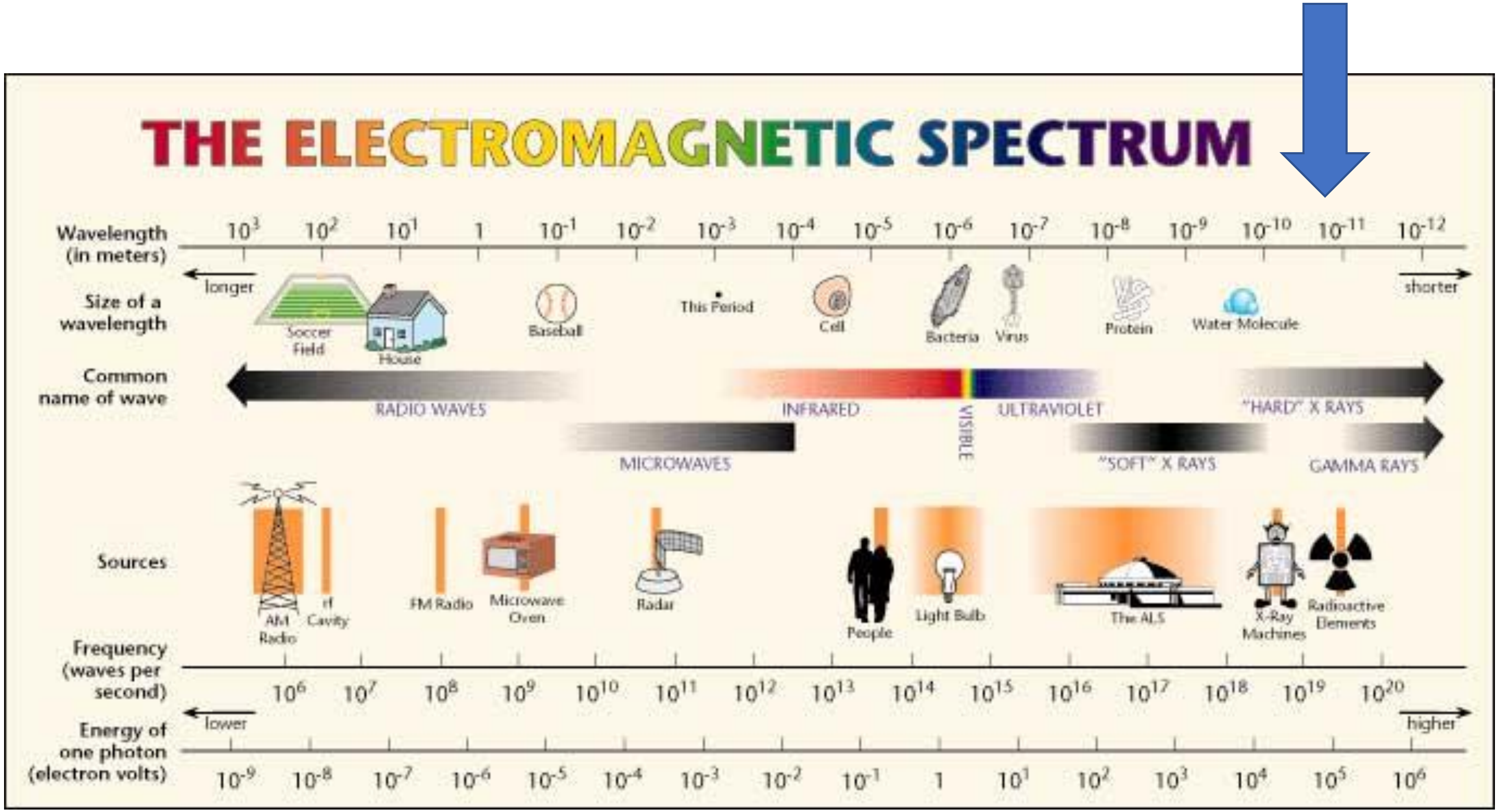
P-32 at **alpha position**, but **beta radiation** because it is P-32



[alpha-P32]ATP

P-32 at **alpha position**, but with **beta radiation** because it is P-32.
For kinase experiments you use **gamma-P32-ATP (gamma position**),
but still it is **beta radiation** because it is P-32**.**

Ionizing electromagnetic radiation



Interaction with tissue

- Ionization can lead to damage of molecules (f. ex. DNA)
- Ionization can lead to production of dangerous compounds (f. ex. free radicals that can damage other molecules)

Radiation dose

- The danger of the isotope is dependent on the activity of the radioactive isotope (decay rate)
- Symbol of activity: A = decay rate
- A =-dN/dt, N = number of nuclei at time t
- Unit: **1 becquerel (Bq) = 1 dis s-1** (dis = disintegration)

- The activity does not tell about the **energy** of the radiation, but about the **speed**
- Older unit **Curie (Ci):** 1 mCi = 37 MBq, 1MBq = 0,027 mCi

Radiation dose

- Determination of the biological result of the ionizing radiation:
- How many ion pairs are created in the radiated tissue
- The amount of energy transferred to the tissue.
- The absorbed energy/mass
- Absorbed dose: $D = E/m$
- Unit: 1 **Gray (Gy)** = 1 J kg-1

Biological effect of radiation

- Measured in **Sv** (**Sievert**). 1 Sv = 1 J/kg. Usually mSv.
- Adjusted from Gray value according to type of radiation

(β and γ radiation: x 1 and alfa radiation: x 20)

and type of tissue exposed to radiation because of risc of cancer in the different tissues (low risc in bone and skin) and risc of mutations in next generation (gonads)

Tissue type	Weight
Bone, skin	0,01
Bladder, breast, liver, esophagus, thyroid gland	0,05
Bone marrow, colon, lung, stomach	0,12
gonads	0,20

Biological effect of radiation

- Measured in Sv (Sievert). 1 Sv = 1 J/kg. Usually mSv.

Background radiation around 4 mSv in Denmark

- One or three month dosimeters used during work with some isotopes such as ^{32}P and ^{125}I. Results normally 0 or 0,1 mSv.
- Risc of cancer/mSv: 0,000055
- Risc of serious genetic defect/mSv in first and second generation: 0,000002

Radiation exposure during a year in Denmark

- Average received during a year 4 mSv
- Medical examination (X-ray etc.) average 1 mSv
- Background radiation is the rest. Half of it is from radon (variable depending on where you live and how your house is built).
- Transatlantic flight 0,05 mSv
- Working with radioactive isotopes seen from dosimeters at MBG

  0 or 0,1 mSv/month (and let us keep it there by working safely)

Higher doses will be obtained if you contaminate your clothes or skin and carry it for longer times.

It will not be detected by dosimeter if you carry it home!!

Radon

- Radon gas comes from the ground.
- Radon breaks down to shortlived radioactive isotopes polonium-218, lead-214, bismuth-214 and polonium-214.
- Radon and several of the breakdown products emit alfa radiation that can damage the lungs.
- Radon exposure will increase the risk of lung cancer especially if you are a smoker.

Eksternal exposure in **mSv/hour** for 1MBq ^{32}P during

normal **work**:

and contamination **accidents**:

Notice: only 1 kBq!

Phosphorus - 32

$^{32}P_{15}$

Half life: 14.3 days
Specific activity: 1.06E+16 Bq.g^{-1}

Risk group: 2
Risk colour: Orange

Main emissions (keV)	Gamma or X		Beta (Emax)		Electrons		Alpha	
	E	%	E	%	E	%	E	%
E1			1710	100				
E2								
E3								
% omitted				0				

Exemption levels	
Quantity (Bq)	1E+05
Concentration (Bq.g^{-1})	1E+03

Transport (TBq)	
IAEA ST1 A1 value	5E-1
IAEA ST1 A2 value	5E-1

EXTERNAL EXPOSURE (mSv.h^{-1}) for an activity of 1 MBq or 1 MBq.m^{-2} (as appropriate)

Point source (30 cm)

Betas, electrons (skin dose): 1.18E-1

Gammas, X rays (deep tissue dose): 0.00E+0

Infinite plane source

Betas, electrons (skin)	
10 cm	1.4E-01
1 m	4.8E-02
Photons (skin)	
10 cm	0.0E+00
1 m	0.0E+00
Photons (deep dose)	
10 cm	0.0E+00
1 m	0.0E+00

10 ml glass vial (100 cm): 1.31E-6

Contact with 50 ml glass beaker: 7.11E-4

Contact with 5 ml plastic syringe: 2.39E+1

The values above do not include Bremsstrahlung radiation.

CONTAMINATION

Contamination skin dose (mSv.h^{-1})	
Uniform deposit (1kBq.cm^{-2})	1.89E+0
0.05 ml droplet (1 kBq)	1.33E+0

Uniform deposit — Droplet

Detection: Recommended probes*	
Alpha	
Beta	+ +
Gamma	
X rays	

Derived limits (Bq.cm^{-2})

Removable contamination	5E+1
Fixed contamination	3E+2

* If no probes are indicated the recommended technique is to use a wipe test in association with a probe or liquid scintillation technique

SHIELDING (mm)

Betas and electrons (Total absorption)	
Glass	3.4
Plastic	6.3

Gamma and X rays (half and tenth value thickness)

	½	1/10
Lead	-	-
Steel	-	-

Radiation protection

Radiation protection at open radioactive sources

- Optimize the radiation protection to keep the exposure as low as possible.

- Be aware of both external radiation and the risc of internal radiation through intake of radioactive material through the mouth or by breathing air contaminated with radioactive material or uptake through skin or wounds

How to lower exposure to radioactive isotopes

- 1. Reduce **time** for exposure.
- Regularly check for contamination of gloves and clothes if you work with ^{32}P or ^{125}I with Geiger-Müller or gamma counter.
- High exposure if you carry isotopes home on your clothes or skin.

- 2. Increase **distance** from isotope

- 3. Use **shields** and **protective clothing** (safety glasses, labcoat, gloves)

General rules for isotope work

- Wear labcoat, safety glasses and gloves and use shield (plexiglass for ^{32}P work and lead glass for ^{125}I work)
- Have Geiger-Müller counter ready for check of radioactivity for ^{32}P work and gamma counter for ^{125}I work
- Check your gloves and labcoat regularly with the counter during the work
- Check for contamination of the area during and after work
- Write the result of the contamination check in the logbook in the room
- Be aware of how to deal with liquid and solid waste (see safety instructions)
- Be aware of the instructions about how to deal with accidents before you start your work. The instructions can be found at the isotope work place.

Rules for work with ^{3}H, ^{35}S and ^{14}C

- Work in a classified room
- After work do a swab test (scintillation counting)
- – remember control sample
- Write the result in the logbook in the isotope laboratory
- If the area is contaminated wash the area and do another swab test
- Find out if your waste is so concentrated that you have to send it to Risø for decommissioning

The following isotopes are being used at the department

Isotope	Maximum energy	Half life
β-radiation		
^{3}H	0,018 MeV	12,3 year
^{14}C	0,159 MeV	5760 years
^{32}P	1,71 MeV	14,3 days
^{35}S	0,168 MeV	87,3 days
γ-radiation		
^{57}Co	0,122 MeV	271,8 days
^{125}I	0,035 MeV	60,1 days

Range and necessary shielding for selected isotopes

Isotope	water	air	Shielding thickness
^{3}H	0,006 mm	6 mm	Not necessary
^{14}C	0,28 mm	24 cm	(1 cm plexiglass)
^{32}P	0,8 cm	720 cm	1 cm plexiglass
^{35}S	0,3 mm	30 cm	(1 cm plexiglass)
^{57}Co			3mm lead or lead glass
^{125}I			3mm lead or lead glass

Shielding of ^{14}C and ^{35}S normally not necessary because of the low range in air.

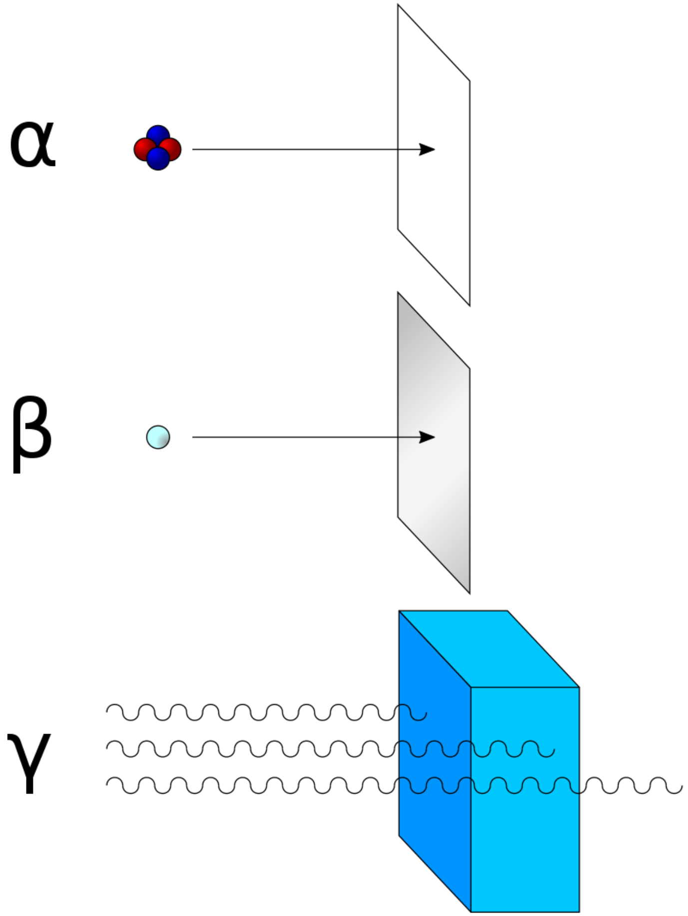
γ emitters (^{57}Co and ^{125}I) have a very long range in air. Shield by lead or lead glass.

If you store ^{32}P solution in glass bottles or use lead glass as protection during ^{32}P work you will get bremsstrahlung (gamma radiation).

Bremsstrahlung

- Bremsstrahlung from elements with high atomic weight like lead.
- If you store ^{32}P solution in glass bottles or lead containers or use lead glass as protection during ^{32}P work you will get bremsstrahlung (gamma radiation).
- Use plastic containers for storage of larger amounts of ^{32}P solutions to reduce bremsstrahlung.
- It can be detected by a gammacounter

Radiation protection



Protection against alpha radiation: paper is enough

Protection against beta radiation (f. ex. ^{32}P): plastic/Perspex
Do not use lead because of development of bremsstrahlung (X-rays)

Protection against gamma radiation:
high molecular weight material such as lead

	Energy	Detection
^{3}H, ^{35}S and ^{14}C	Low energy	Difficult to detect - swab test scintillation counting
^{32}P and ^{125}I	High energy (more dangerous)	Easy to detect by monitor

Radioactive waste

- All waste has to be removed after one year
- ^{32}P waste can be sent as laboratory waste after one year because of short half life (14 days)
- ^{125}I waste is sent as normal laboratory waste or for decommissioning at Risø depending on activity level after one year
- ^{3}H and ^{14}C waste is sent as normal laboratory waste or for decommissioning at Risø depending on activity concentration
- We have an isotope waste room in the basement in Universitetsbyen 1875-K49.
- Remember to notice your name, isotope, date and amount on the list.

Classification of rooms and persons

Isotope work – classification of rooms

Type B isotope laboratory 1874-148 for work with highest amounts of radioactivity, storage of many stock solutions + iodination of proteins with ^{125}I.

Access by key card granted from Niels Sandal or Tinna Stevnsner after instruction.

Type C isotope laboratories for work with lower amounts of radioactivity.

Classified room for isotope work:

- **Type B**: Highest amount of radioactivity allowed
- Room 3131.0.10 in Science Park. Room 1874-148 in Universitetsbyen
- Access allowed by Niels Sandal or Tinna Stevnsner with key card after instruction
- There is a room outside with shower and sink
- Stock solutions of isotopes in freezer
- Work with higher amounts of isotopes
- Iodination with ^{125}I of proteins (free ^{125}I during the procedure)
- Fume hood with regular flow check (anemometer and external company)

Max quantities of isotopes permitted in operations in a type C isotope laboratory:

Isotope laboratory class C	^{125}I	^{32}P	^{14}C	^{3}H
MBq / mCi in use at a time in operations at low risc	100 / 2,7	10 / 0,27	1000 / 27	100000 / 2700
operations at moderate risc	10 / 0,27	1 / 0,027	100 / 2,7	10000 / 270
operations at high risc	1 / 0,027	0,1 / 0,0027	10 / 0,27	1000 / 27

Operations at low risc: Take out from stock solution
Operations at moderate risc: Normal experiments
Operations at high risc: Work with gaseous and dry/dusty isotope material

This information is in the isotope laboratory. Local maximum amount are lower.

Example: Maximum 10 MBq ^{32}P stock solution and maximum 1 MBq ^{32}P in an experiment in a type C isotope laboratory

Places where radioactive material is stored such as freezers, refrigerators, storage rooms, isotope waste containers and isotope waste room should be labelled:

Areas and small containers with radioactive material should be labelled with a radioactivity sign:

Isotope work – classification of persons

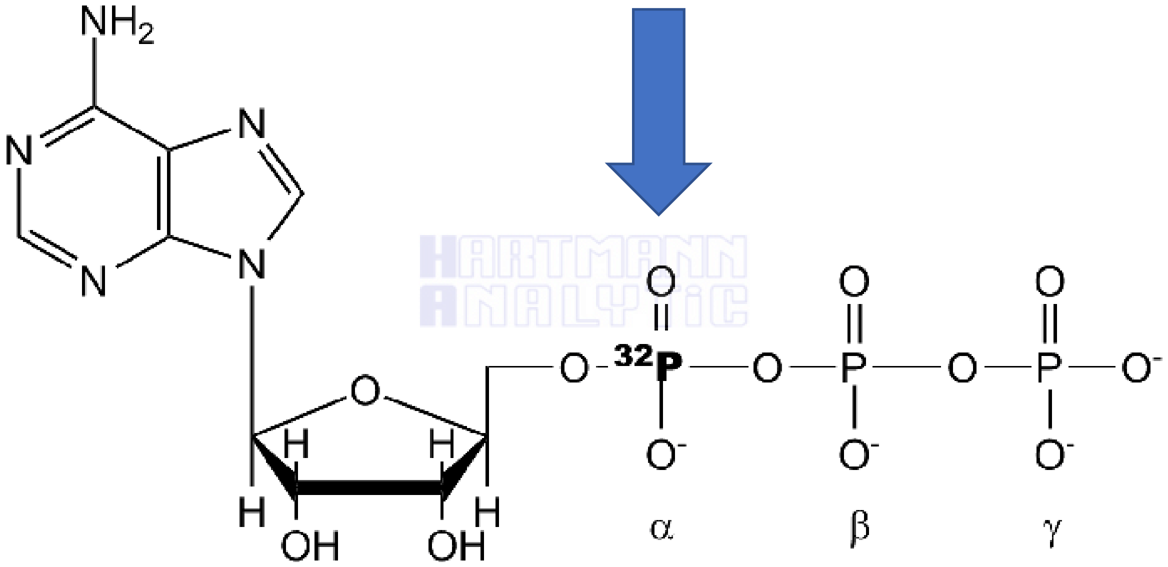
- **Safety assessment** of the person doing the work:
- This is used to classify the person to category A, B or C
- **Category A**: If you under normal circumstances and accidents will receive a dose of more than 6 mSv/year you are in category A. You have to use a **personal dosimeter** with a measuring period of **1 month**.
- **Category B**: Work with beta emitters with medium or high energy.
- ^{32}P and ^{125}I work is normally in category B. You have to use a **personal dosimeter** with a measuring period of **3 months**.
- Iodination of proteins with ^{125}I with gaseous ^{125}I during the process is done in the fumehood in type B isotope laboratory. Urine test.
- **Category C**: F. ex. work with radioimmunokits (RIA kits).

- If you are pregment you have to report this as there are special rules for pregment women.

Instruction in the work with isotopes

- If you are going to work with isotopes you have to read the chapters about radioactivity in the safety regulations and you have to be instructed by one of your isotope coordinator:
- Tinna Stevnsner (tvs@mbg.au.dk)
- Niels Sandal (nns@mbg.au.dk)
- Additional instruction from your research group
- Then you will be on the list at MBG web site as a person instructed in work with radioactive isotopes.
- If your type of isotope work is changed such as larger amounts or new isotopes you have to contact your isotope coordinator for a new safety evaluation to see if this leads to a change in the use of dosimeters.
- New instruction has to take place after the change in the isotope work.

Exercise 1



[alpha-P32]ATP

Does this molecule give rise to alpha, beta or gamma radiation?

Exercise 2

- Beta radiation is

- Helium nuclei
- Electrons
- Elektromagnetic radiation

Exercise 3, 4 og 5

How do you protect you against radiation from:

Excersize 3: H-3 (tritium – beta radiation)

Excersize 4: P-32 (phosphorus-32)

Excersize 5: I-125 (iodine 125 – gamma radiation)

For each of the isotopes: Is radiation shield not necessary or would you use plastic (plexiglass) or lead/lead glass?

Exercise 6

What happens if you use lead glass as shield against P-32 radiation and plastic as shield against radiation from I-125?