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Ra-226 Re-use / Recycle Presentations and Round Table
US DOE Isotope Program, IRP

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Radiation protection issues associated to design and operation of facilities using Ra-226 for production of isotopic generators for alpha-radioimmunotherapy

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My brief backgtound in relation with Ra-226

- Radiological properties of radium 226
- The radium 226 and radon 222 radiation protection
- Radon 222 measurements methods and examples of equipment
- Alternative to Ac-225/Bi-213: Lead 212 alpha-immunotherapy: A French Approach but many similar design/operation concerns
- Some design requirements for a facility dealing, for instance, with with Ra-226
- Design / Operation for process steps, for normal, incidental and accidental situations
- Management of secondary waste
- Conclusion: Safety first

Outlines

- Radiological properties of radium 226
- The radium 226 and radon 222 radiation protection
- Radon 222 measurements methods and examples of equipment
- Alternative to Ac-225/Bi-213: Lead 212 alpha-immunotherapy: A French Approach but many similar design/operation concerns
- Some design requirements for a facility dealing, for instance, with with Ra-226
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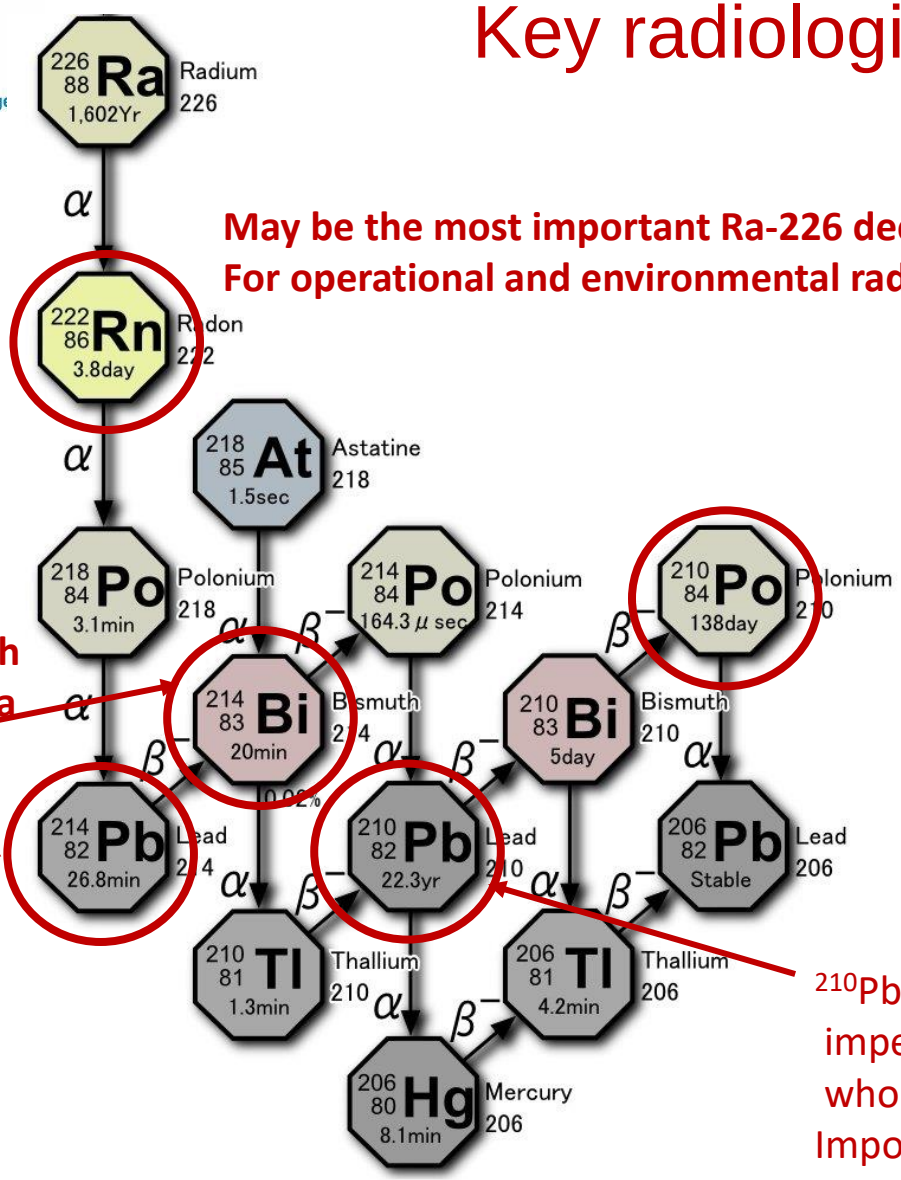
- Management of secondary waste
- Conclusion: Safety first

Radium 226 decay chain: Key radiological properties



May be the most important Ra-226 decay product
For operational and environmental radiation protection

Very high radiotoxicity such as poisons, according to recent events

Both have high Energy gamma rays

^{210}Pb: 22,3 years half-life, but doesn't impede fast secular equilibrium of the whole ^{226}Ra chain (few days)
Important as cumulate in air filters

Radiation protection concerns when dealing with ^{226}Ra from disused sources

Main Ra-226 radiological hazards are:

- External exposure from gamma rays emitted by radium 226 and its progeny

Co-60	**7,80E-04**
Ra-226 averaged	**3,40E-04**
Cs-137	**8,70E-05**

Unit: mSv/h/MBq at 1m

Gamma constant of Ra-226 in equilibrium with its its progeny

- Internal exposure from:

➢ Ingestion of radium 226 (and its decay products)
➢ Inhalation of radon 222, especially its daughter products

Exposition from radium 226 and radon 222

- Radium 226: alpha emitter (~4.9 Mev) + **185 keV gamma ray ➔ external exposure mainly from progeny products when in equilibrium**: 352 keV (38%), 609 keV (46%), 1120 keV (15%) and **1764 keV (15%)**

- Radon 222: main internal exposure
  - Equivalent dose delivered by radon 222 itself by inhalation *is negligible*
  - **Equivalent dose is delivered by short-lived decay products of radon 222**

- Inhalation of 1 Bq ^{222}Rn exposes an individual to 5.56 E^{-09}J (34 710 MeV) = sum of **potential alpha energies** of its progeny

- Explains high radiotoxicity of radon and related high risk of lung cancer for exposed people such as workers in uranium (or other) mines.

Exposure from radon 222 and its progeny

Radon 222 decay products				Energy per alpha particle		For 1 Bq of Rn-222	
		Half-lives		Mev	E^{-12} Joules	MeV/Bq	E -10 J/Bq
Polonium	218	3,05	minutes	13,69	2,19	3615	5,79
Plomb	214	26,8	minutes	7,69	1,23	17850	28,6
Bismuth	214	19,9	minutes	7,69	1,23	13250	21,2
Polonium	214	164	Micro-seconds	7,69	1,23	$2,0E^{-03}$	$3,0E^{-06}$
Total						**34715**	**55,6**

Radon 222 measurement methods (very summarized)

- Sampling radon on a short time (~1 hour) in a specific place; **scintillation cells** (with ZnS), or **gamma spectrometry** of sample taken in a standardized container**, alpha counting**

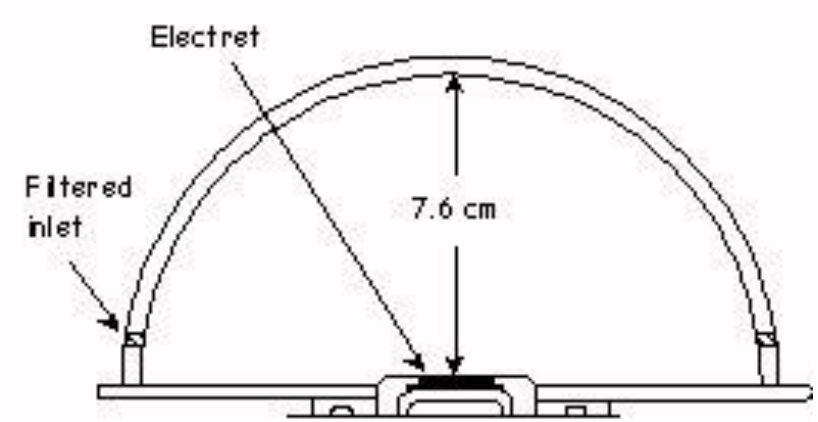
- Integrated measurement methods that needs a longer sampling time ~1 week to integrate daily variations of volumic concentration: **Solid State Nuclear Trace detectors, use of charcoal then liquid scintillation counting or gamma spectrometry, electrostatic devices**,

- Continuous sampling and measurement, which should be adapted to the dynamics of radon generation and transport phenomena: **ionization chamber (gaz circulation, or diffusion) or gamma spectrometry; sampling on filter and alpha spectrometry**

- *Methods are codified in national and international standards*

Passive Radon Measurement Methods

Passive monitoring techniques (Solid State Nuclear Trace detectors SSNTD and ion chamber detectors) and continuous monitoring techniques (Solid State Silicon and Germanium Detectors).



Electret ion chambers are commonly used **for passive** radon measurements.
Two types of E-PERM devices (the S- and H-chambers) are used (see www.radelec.com

Kit for Radon-222 spot measurement using scintillation flasks

Radiation protection: Active measurements of radon 222 - Some examples:

- ✓ Continuous measurements for Rn-222 (Radonova)

Corentium: Alpha spectrometry as Rn-accumulative method

AlphaGuard spectrometry as Rn-accumulative method
Detector: 0.62 L pulsed ionization chamber +
Alpha spectroscopy

ATMOS (radonocva) pumps filtered air into a pulsed ion chamber

Many other equipment exist!

Radiation protection: Active measurements of radon 222 - Some examples of equipment

- ✓ Portable/personal electronic dosimeters

e.g. the AlphaE (Radonova)
3 pulses/hour at 100 Bq/m^3 thus compatible with the 300 Bq/m^{3}limit

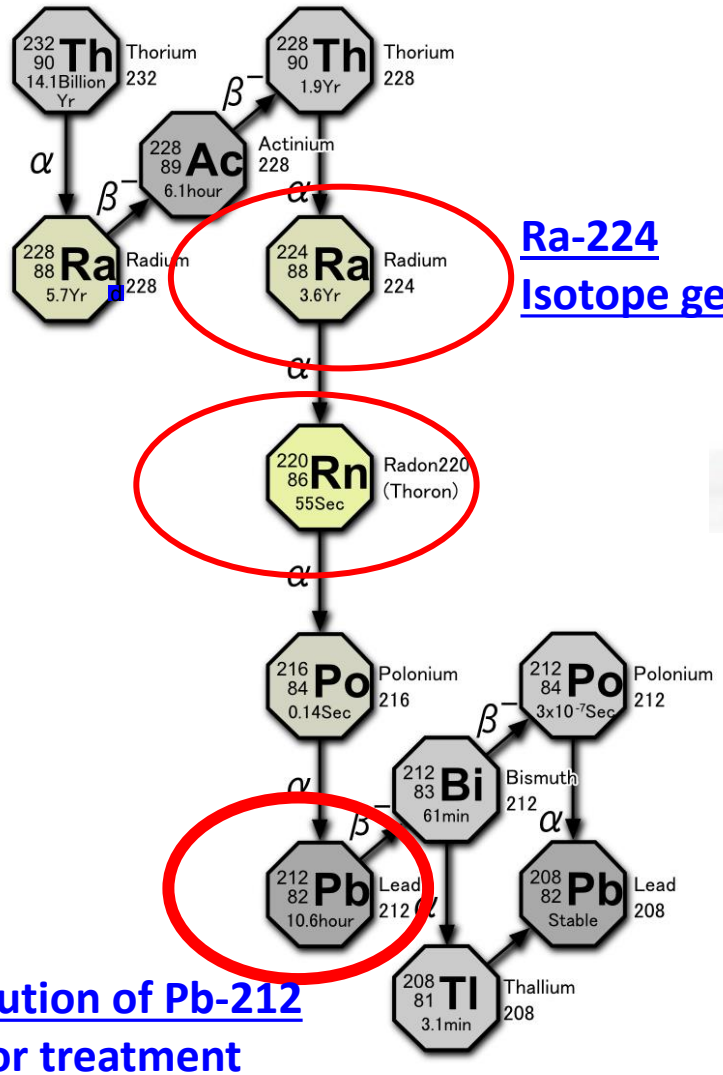
Exposure from radium 226
Radiation protection means for process steps

- ✓ External exposure: use of shields, e.g. some process steps in a shielded glove box or a 'light' hot cell depending on the ^{226}Ra source term (depending on maximum activity used in a single step).
- ✓ Glove box should be shielded, e.g. with leaded plexiglass panels.
- ✓ Glove boxes / hot cells should have nuclear ventilation and filtration (ISO 17873:2004).
- ✓ Filtered air should be released in a stack to dilute radon in order to limit dose impact to the reference (critical) group.
- ✓ In many countries, it is mandatory to quantify amounts of gaseous (Rn-222) releases

Exposition from radium 226 and radon 222
Radiation protection for process steps

- ✓ In most cases, Personal Protective Equipment (PPE) will be limited as the main effort is put on collective radiation protection.
- ✓ Personal dosimetry: passive and active ➔ **mandatory**, even for radon dosimetry when needed
- ✓ Permanent control in the process premises of:
  - ✓ Airborne alpha-beta contamination,
  - ✓ Airborne radon 222 volumic concentration (recommended maximum level: 300 Bq/m^3 , if no specific radon PPE)
  - ✓ Ambiant gamma dose rate at safety relevant places

Alternative to Ac-228: Pb-212 alpha-radio immunotherapy



Ra-224 Isotope generator

Elution of Pb-212 for treatment

AdvanCell Isotopes ^{212}Pb Generator

Ra-224/Pb-212 generator from US DoE

Example of the Maurice Tubiana Laboratory in France

- French Orano Group has developed alpha-radio immunotherapy based on Lead 212, daughter product of Th-232 ➔ Ra-228 ➔ Th-228b ➔ .. ➔ Ra-224 generator to deliver Pb-212 to the patient
- Reason: After the 2ndWW, France used monazite ore to develop the French Civilian and Defence nuclear programs based on uranium, but large amounts of Th-232 were generated as a by-product and stored at CEA facility.
- Process was developed by highly skilled chemists in La Hague spent fuel reprocessing Plant
- Pre-pilot plant operated in Bessines Orano site (former uranium mine) for production of the first Ra-224 generator to start human in-vivo testing in the US (Alabama)
- Pilot production plant built at Bessines (Laboratoire Maurice Tubiana)
- Production plant built in Texas (US)

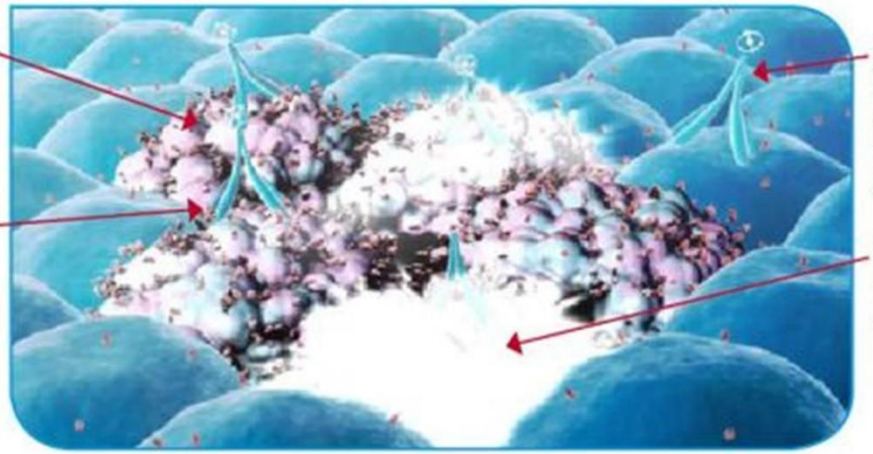
Alpha-Radioimmunotherapy with Lead 212

How ^{212}Pb Works

An example of TAT: Radioimmunotherapy using ^{212}Pb compounded with an antibody to attack and destroy cancer cells

1. Cancer cells express a specific antigen

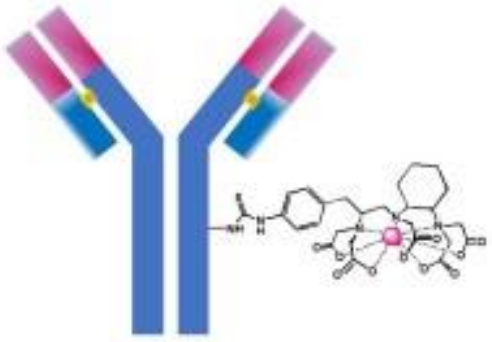
2. The **antibody** recognizes and targets the cancer cell's antigen



3. The **chelating agent** links the antibody to the ^{212}Pb

4. ^{212}**Pb** destroys the cancer cell

Antigen: *A substance which provokes an immune response.*
Antibody: *Recognizes and targets cell-specific antigens on cancer cells.*
Chelating Agent: *A "molecular cage" used to attach isotopes to monoclonal antibodies.*



Alternative to Ac-228: Lead 212 alpha-immunotherapy
The *Maurice Tubiana* Laboratory in France

Stack for Rn-220 dilution

Limited PPE for workers as main effort is put on the shielding and **confinement** of the process equipment

Example of the Maurice Tubiana Laboratory in France
Quality control laboratory

Exposition from radium 226 and radon 222
Radiation protection Ra-226 DSRS dismantling operations

Dismantling of ^{226}Ra sources and Ac-228 separation/purification performed in close and ventilated equipment: need for shielded glove box(es)

No ventilation extraction

➔ Shielded walls (leaded plexiglass,..)

➔ Nuclear ventilation (ISO 17873) to:

- Filter radioactive particles, arerosols,
- Extract radon and drive it to an exhaust (stack), and quantify radon releases

E.G. of Some design requirements:

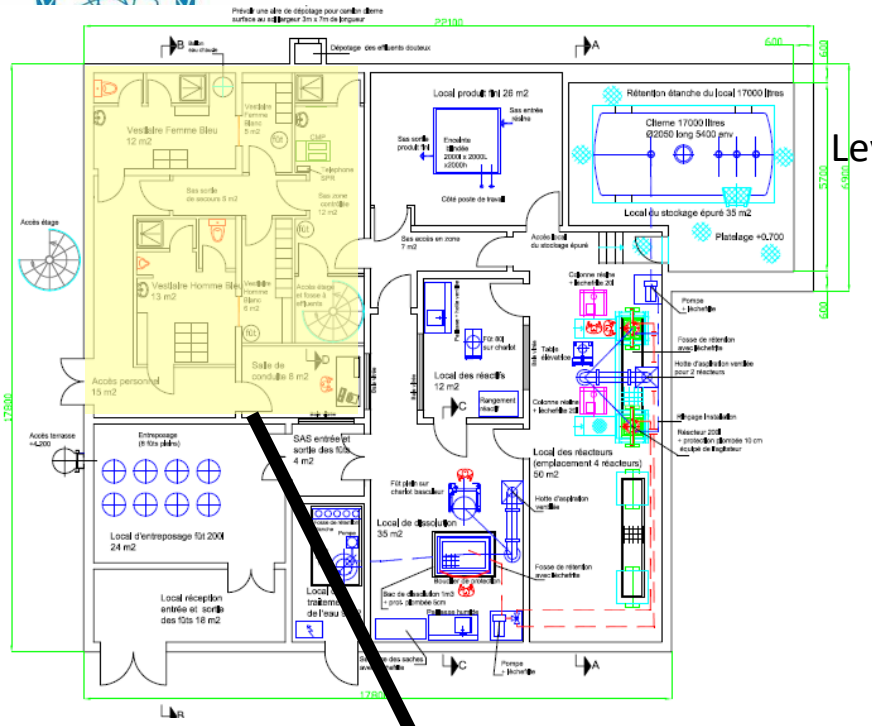
Waste disposal sinks and Drainage Pipes

✓

X

Use of absorbent paper on benches and in glove boxes

Locker rooms in a radiochemical laboratory



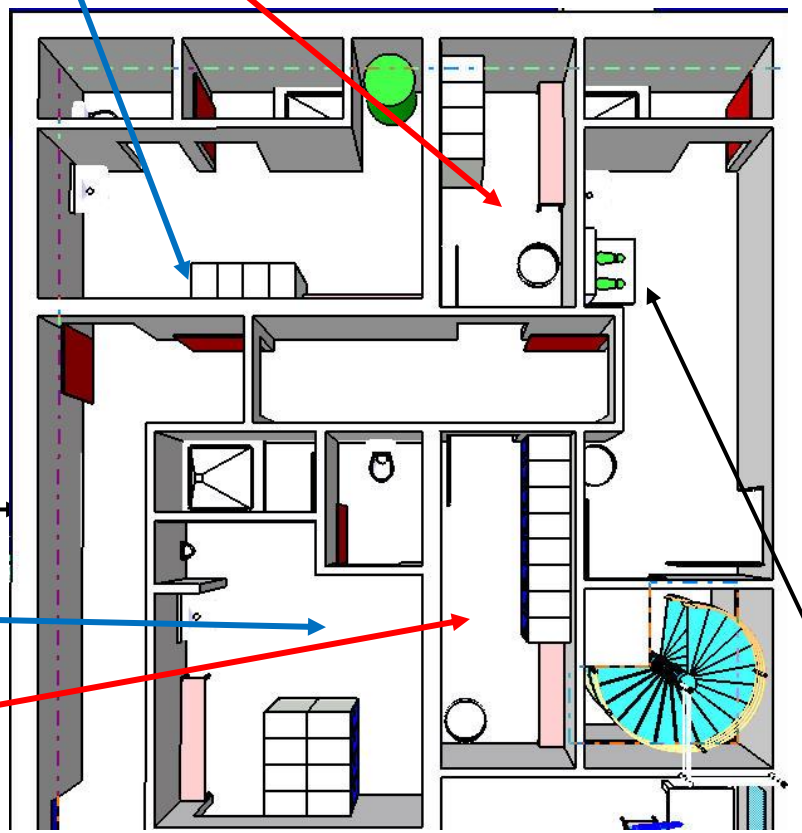
Changing rooms

Cold / Blue changing room for men

Hot / White (active) changing room for men

Cold / Blue changing room for women

Hot / White (active) changing room for women



radiological monitor hands-feet-clothes

Design for process: incidental and accidental situations – some tips

Incidental/accidental situations – examples:

- If cut-off of electrical supply => static confinement for some equipment (glove boxes/hot cells); use of diesel generators

- Break-down of a glass container, ion exchange resin column, etc. trays to recover liquid spills, materials/surfaces easy to decontaminate

- Emergency teams with special PPE, special intervention trainings,

- Fire: inform/train the fire brigade to specific hazards/specific procedures/ equipment needed

All these situations should be:

➔ described in the main safety documents SAR/EIA/safety case

➔ emergency plan/procedures

Management of secondary waste

Secondary waste will be generated in the processes:

- envelopes/debris from dismantled Ra-226 sources
- at the irradiation facility premises (targets, other)
- Process waste: spent IER columns, laboratory glass/other equipment, wipes, etc.
- Waste from cleanup of glove boxes / hot cells, etc.
- Spent HEPA filters,
- All items resulting from implementation of **Good Manufacturing Practices** and sound radiation protection practices

- Secondary waste should be:
  - Packed e.g. in plastic bags, then in 100 L or 200 L drums
  - Characterized, e.g. by gamma spectrometry and/or by the dose rate conversion method (no sampling recommended)
  - Stored in a ventilated area (radon 222 issue for Ra-226 bearing waste)

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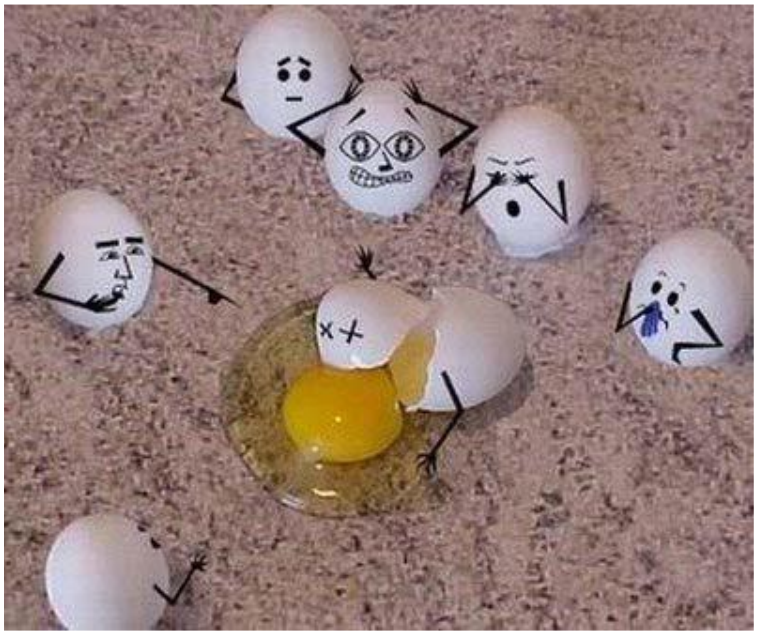
Safety First!



Thank you for your attention