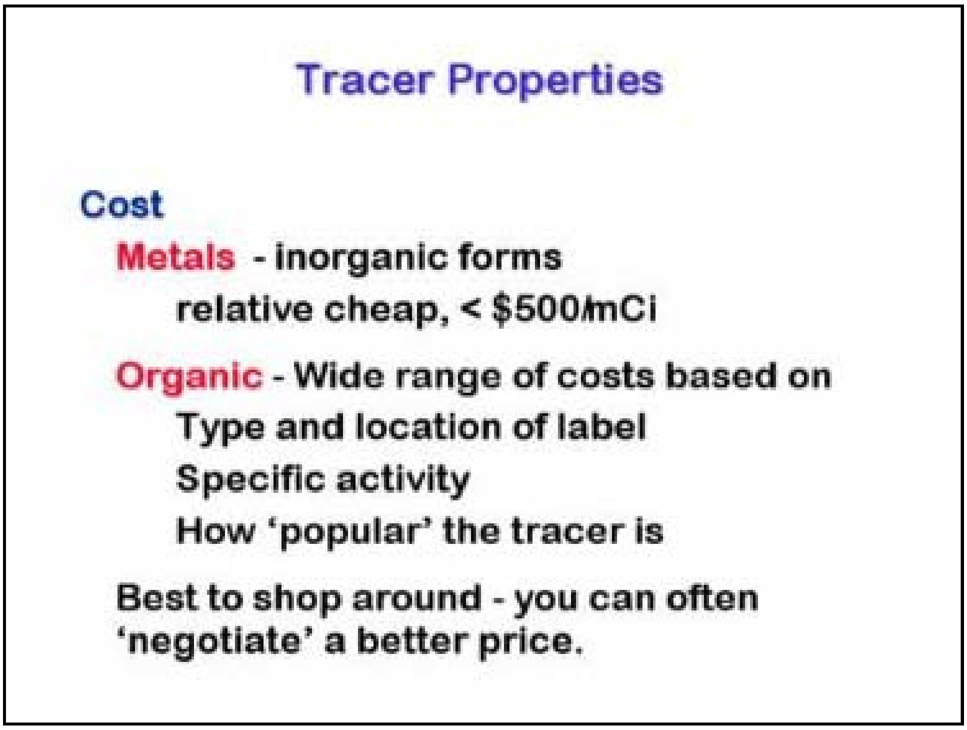
Fényképalbum8

szerző: PGY



Tracer Properties

Cost

- **Metals** - inorganic forms
  - relative cheap, < \$500/mCi
- **Organic** - Wide range of costs based on
  - Type and location of label
  - Specific activity
  - How ‘popular’ the tracer is

Best to shop around - you can often ‘negotiate’ a better price.

Tracer Selection

There are several factors to consider when choosing a radiotracer.

- It must 'follow' the conditions being evaluated.
- The half-life must be long enough to provide sufficient activity to measure during the study
- The type of radiation must be measurable.
- The cost must not be prohibitive.

These limits often prevent the successful use of tracers.

Pros and cons of radionuclides in analytical chemistry

Pros.

Sensitivity - ppb level.

Example

You want to detect 1 ppb (10^{-9}g) in a one gram sample - only 0.1% tracer is needed.

Assume

half-life is 10 days (14400 minutes)
atomic weight = 100
detector efficiency is 10%

Sensitivity example

N $= N_o e^{-0.693\,t\,/\,t_{1/2}}$

No $= 10^{-12} / 100 \times 6.02\text{x}10^{23}$

$= 6.02 \times 10^{9}$

For a one minute count time

N $= 6.02\text{x}10^{9}\ e^{-0.693\,(1\text{min})\,/\,14400\text{min}}$

= 144882 dpm

= 14488 cpm at 10% efficiency

This is pretty easy to detect.

Other advantages

Uniqueness

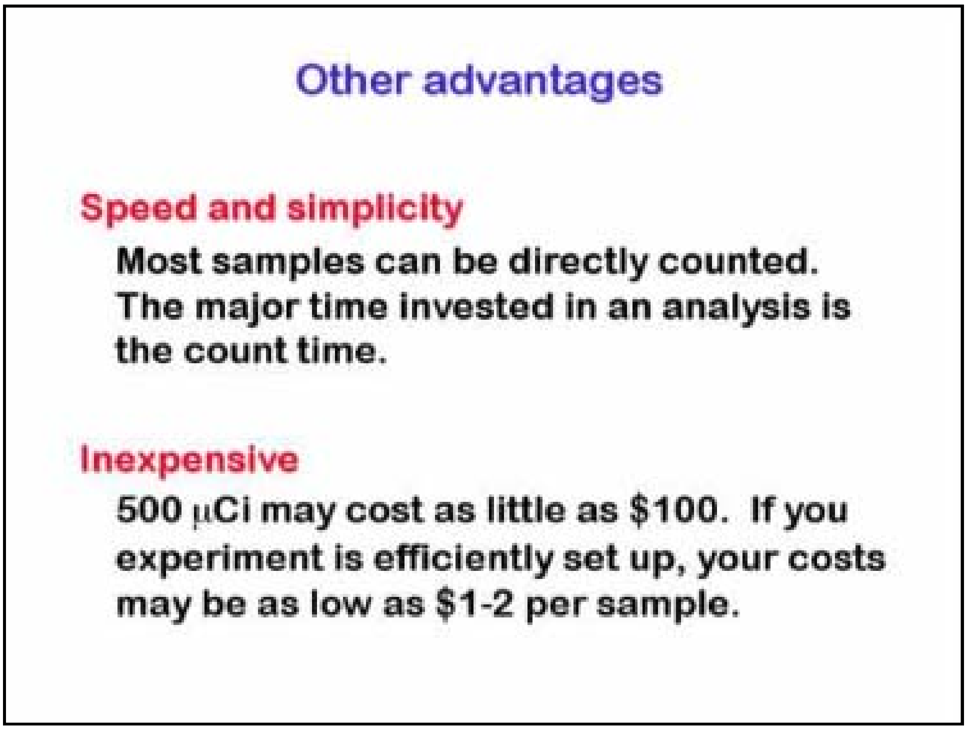
You are looking at a nuclear property which is independent of the chemical form which reduces interferences.

Few nuclear interferences

Most nuclides can be distinguished from each other.

Versatility

Most elements have good tracers.



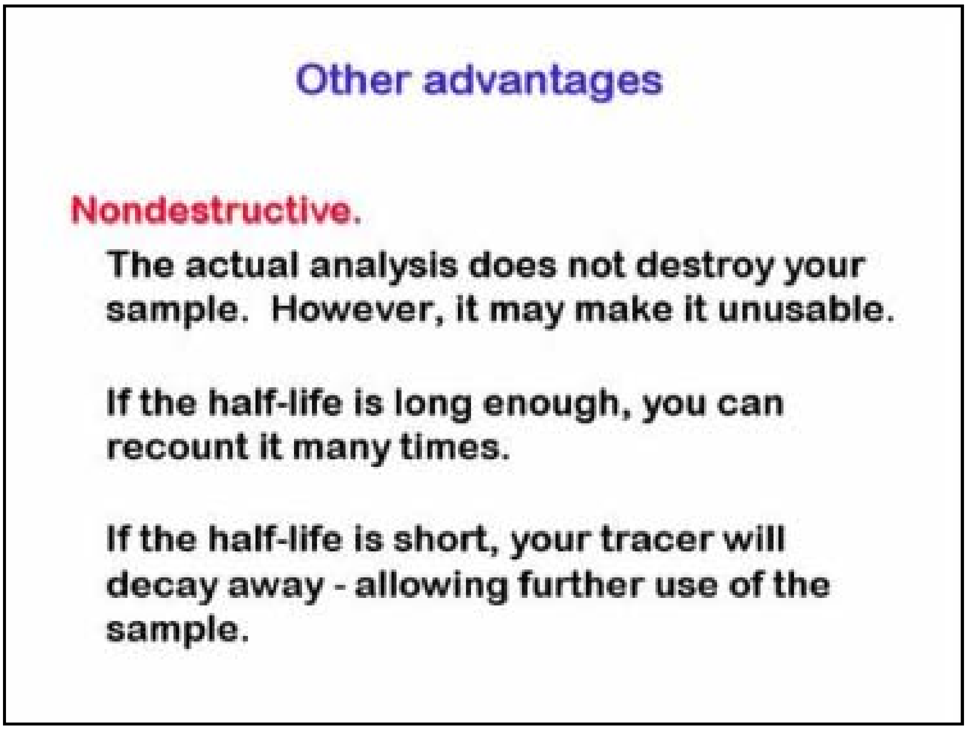
Other advantages

Speed and simplicity

Most samples can be directly counted. The major time invested in an analysis is the count time.

Inexpensive

500 μCi may cost as little as $100. If you experiment is efficiently set up, your costs may be as low as $1-2 per sample.



Other advantages

Nondestructive.

The actual analysis does not destroy your sample. However, it may make it unusable.

If the half-life is long enough, you can recount it many times.

If the half-life is short, your tracer will decay away - allowing further use of the sample.

Disadvantages
Yes, there are many!

Availability

Not all radioisotopes are commercially available or in a form that you can use.

Degradation

Radiation can break chemical bond.

Impurities

These are usually not listed. The percent or types of impurities are no known.

Disadvantages

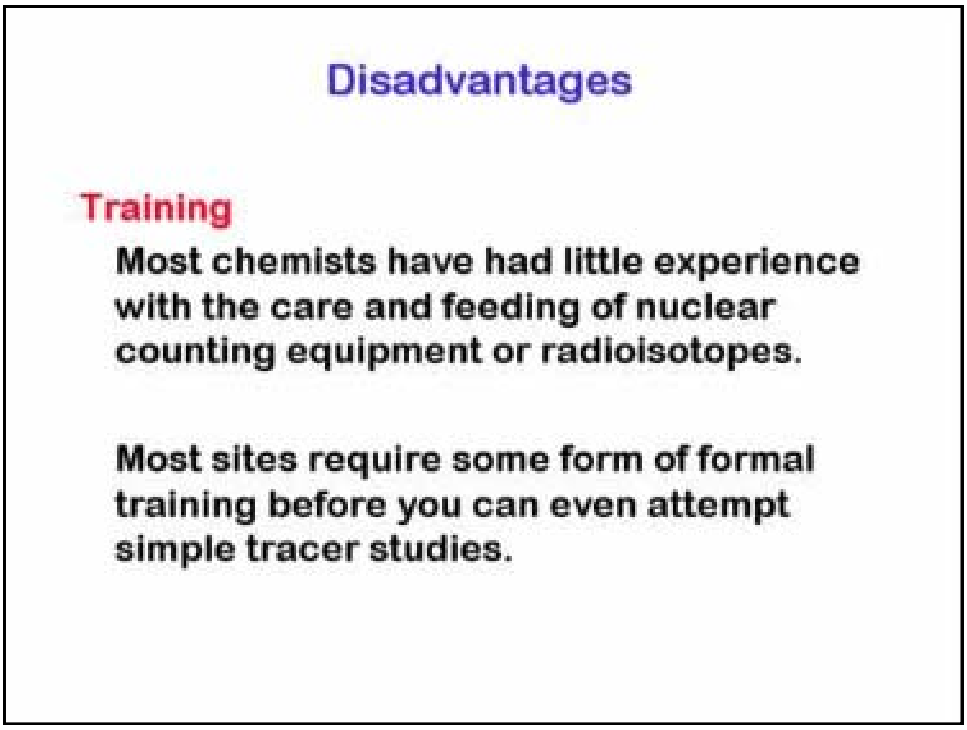
Isotope effect

A change in the reaction rate, chromatographic separation or some other rate dependent measurement.

Worst for ^{3}H - 3 times the mass of ^{1}H.

^{14}C is not as bad - $^{14}C/^{12}C$ ~5%

Regardless of the isotope, it will not be much of a problem is the tracer is only a small portion of your sample species.

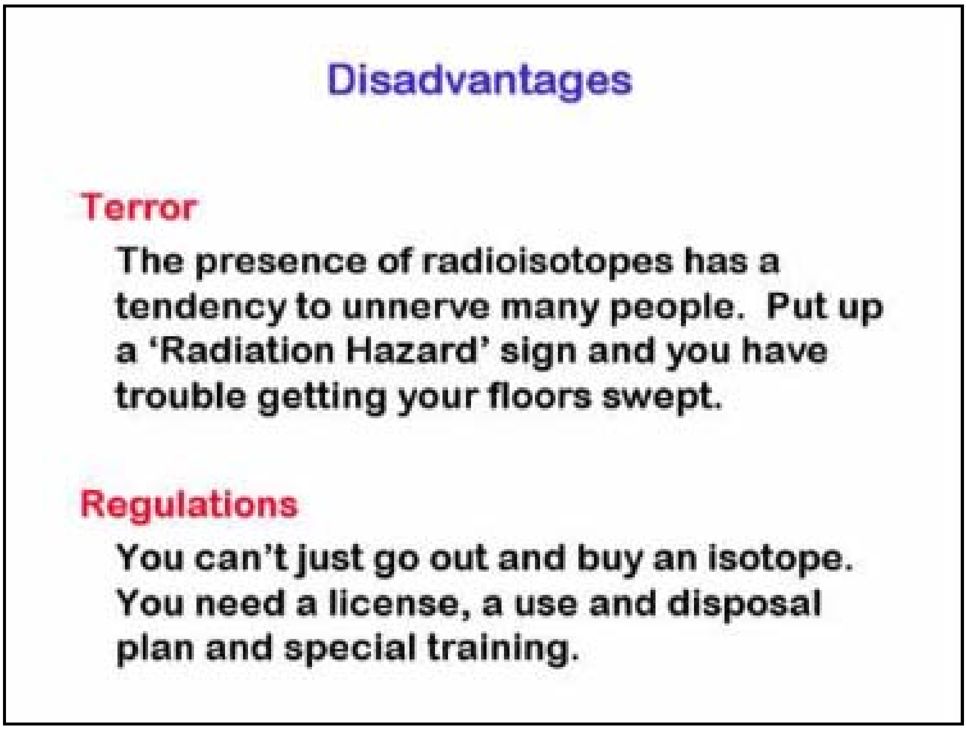


Disadvantages

Training

Most chemists have had little experience with the care and feeding of nuclear counting equipment or radioisotopes.

Most sites require some form of formal training before you can even attempt simple tracer studies.



Disadvantages

Terror

The presence of radioisotopes has a tendency to unnerve many people. Put up a ‘Radiation Hazard’ sign and you have trouble getting your floors swept.

Regulations

You can’t just go out and buy an isotope. You need a license, a use and disposal plan and special training.

Selection of a tracer

Assume that you have the proper training, license and equipment.

Now you need to buy a radiotracer.

The process and options are different than ordering a chemical.

Lets review the decisions you must make.

Selection of a tracer

For most studies, its best to purchase your tracer in exactly the same chemical form.

For inorganics, the choices are pretty limited.

Organic compounds, ^{3}H and ^{14}C labeled, require that you know the type of labeling you need.

Labeling

Two choices

UL - uniformly labeled

- the radioisotope can be in any position in the compound.

Example - UL ^{14}C toluene

UL $^{*}C_6H_5{}^{*}CH_3$

Label is on any carbon.

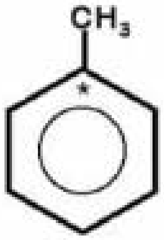
Ring UL $^{*}C_6H_5CH_3$

Label is one any of the carbons of the ring.

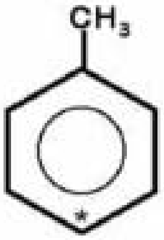
Labeling

SL - specific label

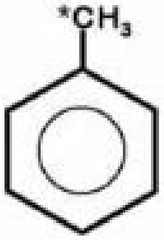
- the label is in a single, known position on the compound.



SL C-1



SL C-3



SL C-7

Labeling

Specific labels are not available for every possible location.

- Depends on the chemistry involved to make it.
- Cost is also a factor. If you are the only person who wants it, the company that can make it will charge big bucks.
- If the tracer you want can be cheaply made, you should consider do it yourself.

Labeling

Example

Following biochemical pathways of a drug.

Using a UL label. Any species that become labeled represent a portion of the pathway.

SL label. Will show the fate of a specific C.

If the species is expected to remain intact, always opt for the cheapest form - typically a UL label.

Specific activity

This is a measure of the radioisotopic purity of your tracer.

The specific activity (SP) determines the ultimate detection limit for tracer based methods.

Carrier free - all of the species of interest contains the radioisotope. Available for some simple inorganic species - based on source, mode of decay and chemistry involved in producing it.

Specific activity

Specific activity is always a concern for ^{14}C labeled species. Lets see why.

Example

Assume one gram of UL labeled benzene.

If every benzene molecule contained a ^{14}C

1 g sample / 78 g/mol

= 0.01282 moles benzene

= 0.01282 moles of ^{14}C label

Example

The half-life of ^{14}C is 5730 years so the activity of our sample should be:

$$N = 0.0128 \times 6.02\times10^{23} \times e^{\frac{-0.693\,(1\ \text{min})}{3.01\times10^{9}\ \text{min}}}$$

$= 1.77 \times10^{12}$ dpm

$= 0.798$ Curies

(This is an enormous amount of activity)

Specific activity

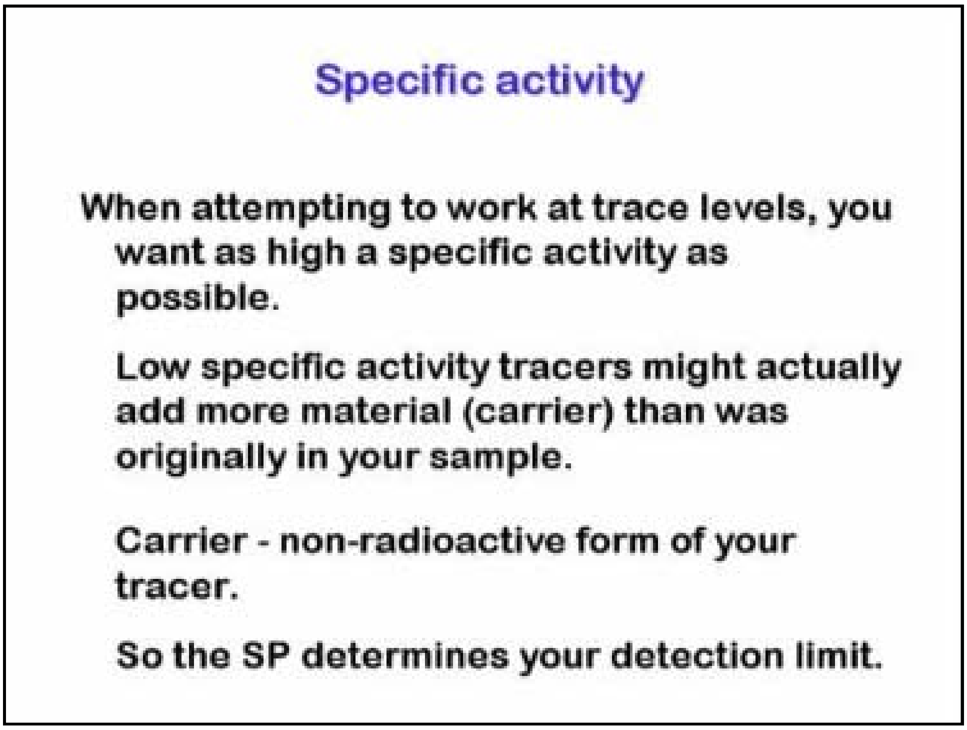
You typically want to work with lower levels of activity for a tracer study.

In addition, you seldom can purchase ‘pure’ radioisotopes.

Specific Activity

SP = Activity / moles, grams, ...
Commonly use mCi/mmol

This value will be given when you look up a tracer in a catalog.



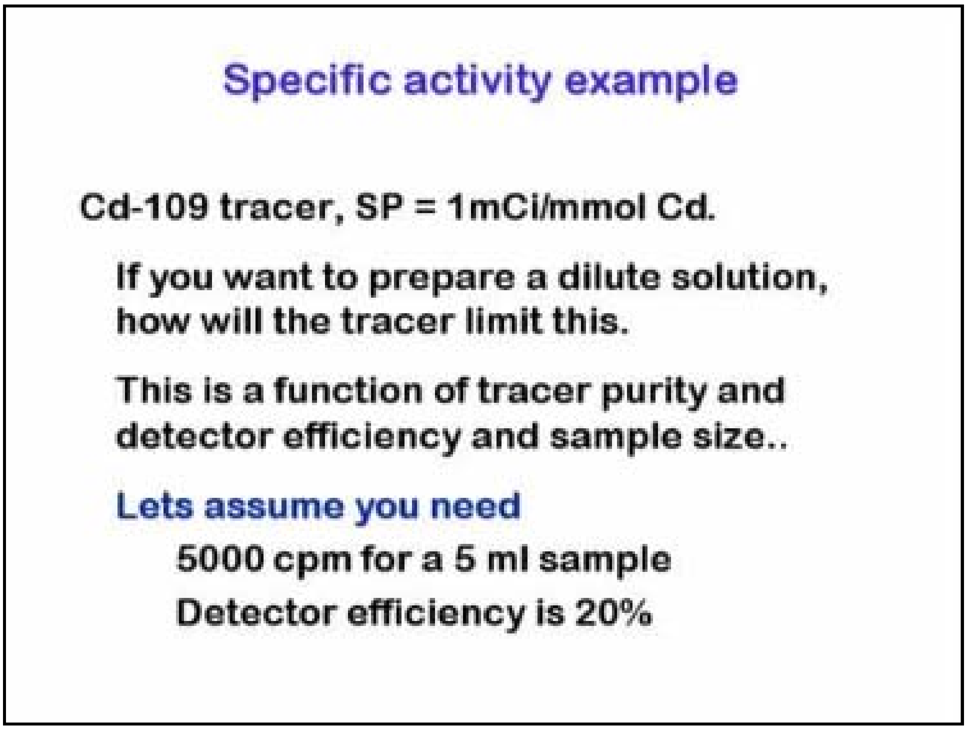
Specific activity

When attempting to work at trace levels, you want as high a specific activity as possible.

Low specific activity tracers might actually add more material (carrier) than was originally in your sample.

Carrier - non-radioactive form of your tracer.

So the SP determines your detection limit.



Specific activity example

Cd-109 tracer, SP = 1mCi/mmol Cd.

If you want to prepare a dilute solution, how will the tracer limit this.

This is a function of tracer purity and detector efficiency and sample size..

Lets assume you need

- 5000 cpm for a 5 ml sample
- Detector efficiency is 20%

Specific activity example

Activity needed in 5 ml

5000 cpm / 0.2 cpm/dpm = 25000 dpm

25000 dpm / 2.22×10^{12} dpm = 1.13×10^{-8} Ci
= 0.0113μCi

0.0113μCi/5ml = 2.26 μCi /liter
= 2.26 μM Cd from tracer

2.26 mM x 109 = 246 μg / liter (0.246 ppm)

So you can work with lower concentrations.

Tracer properties

You must also consider the radiation properties of the tracer.

half-life

Isotope dependent.

Must pick an isotope that meets the needs of your study.

It must also be commercially available.

Tracer properties

Half-life considerations.

The half-life should be significantly greater than the duration of your study.

If you want to study a reaction that takes 24 hours to conduct, the tracer should have a half-life of at least a week.

If this can't be accomplished, you must correct for the amount that decays.

Tracer properties

Half-life considerations.

You also want the half-life to be as short as possible to reduce problems with disposal.

Examples - Ni isotopes

Isotope	$t_{1/2}$	Example study
Ni-56	6.1d	5 min electroplate study
Ni-59	7600a	'Time capsule'radiotimer.
Ni-63	100a	Bearing wear
Ni-65	2.52h	Ni uptake by bacteria

Tracer properties

Half-life considerations.

Not all elements will have a half-life suitable for a study.

Example - Copper isotopes

The longest half-life is 61.7 hours.

Very short half-life isotopes will not be available commercially.

Tracer Properties

Mode of emission.

This is a major concern.

You need an isotope that emits something that you can detect.

C-14, H-3 and Ni-63 are β emitters

You must use liquid scintillation.

Most elements with $Z < 83$ will emit γ along with either β^+ or β^- emission.