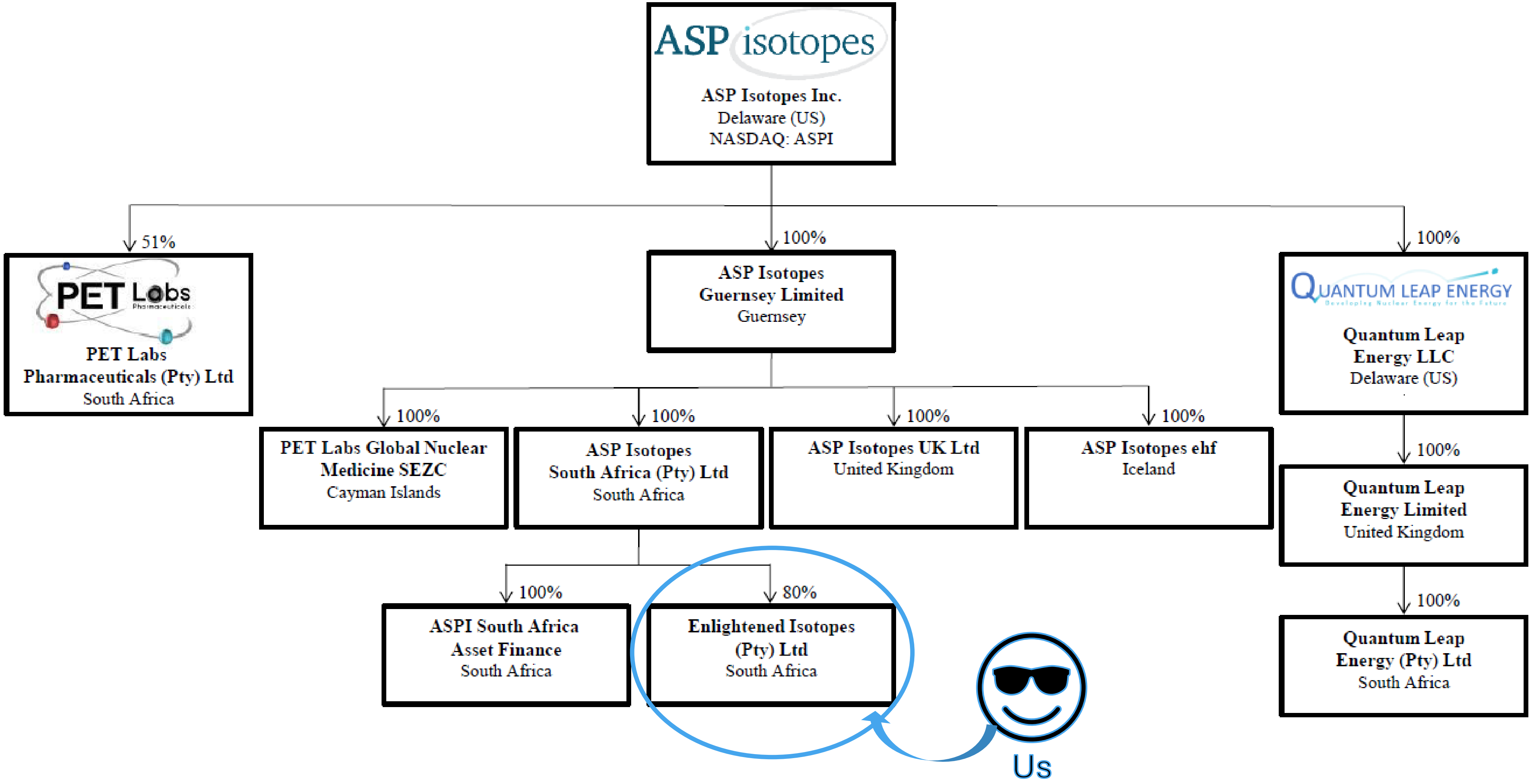
Enlightening medicine with quantum-enriched isotopes

Leerin Perumal

National Science & Technology Forum

19 November 2025

Enlightened Isotopes: “all things lasers”



Meet the Enlightened Isotopes team

We're expanding
the team

- x 4 Physicists
- x 2 Chemists
- x1 Mathematician
- x1 Engineer
- x1 Technologist
- x3 Specialised technicians
- x 2 Lab assistants
- x1 Project manager

Meet the Enlightened Isotopes team

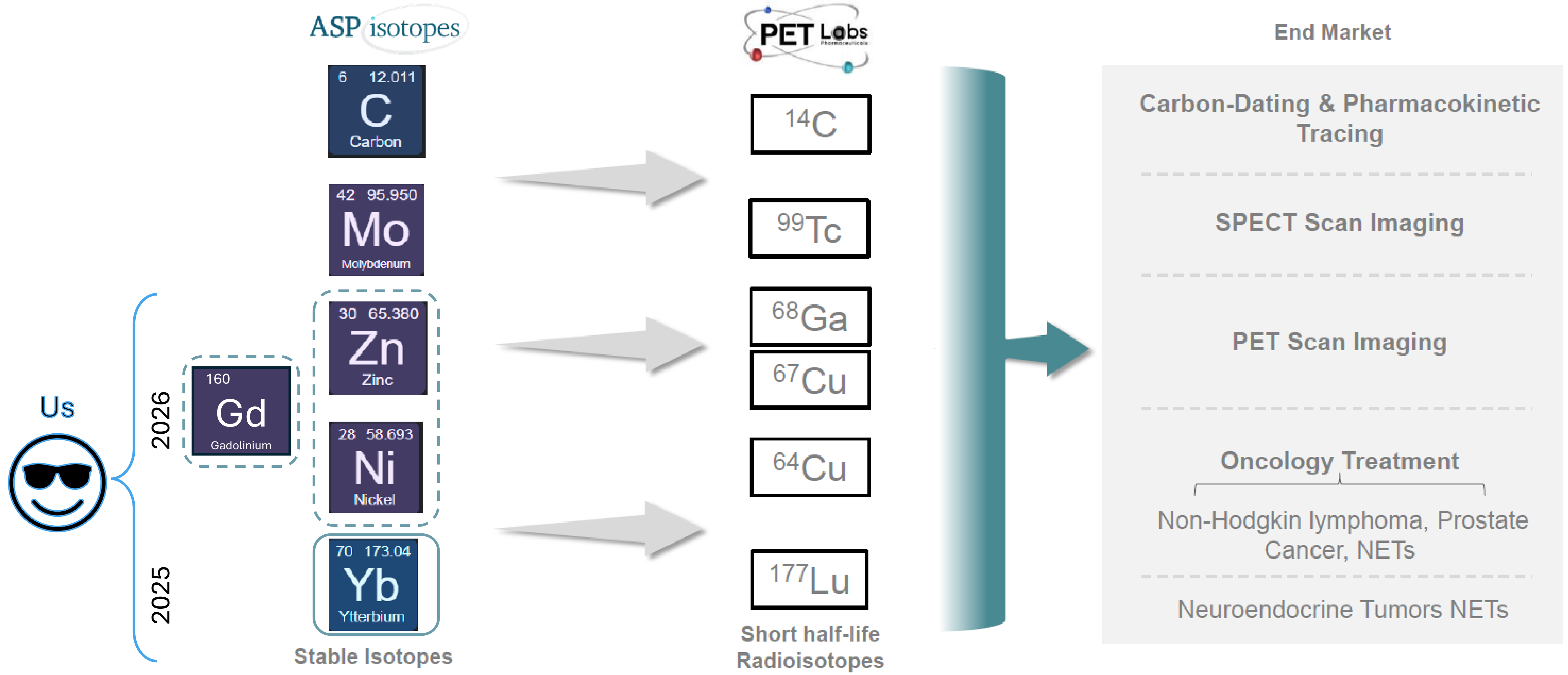
We're expanding the team

Our research partners

WITS UNIVERSITY

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT

Enlightened Isotopes: “all things lasers”



Our first enrichment facility is for Yb-176

Us

ASP isotopes

70 173.04
Yb
Ytterbium

Stable Isotopes

PET Labs

^{177}Lu

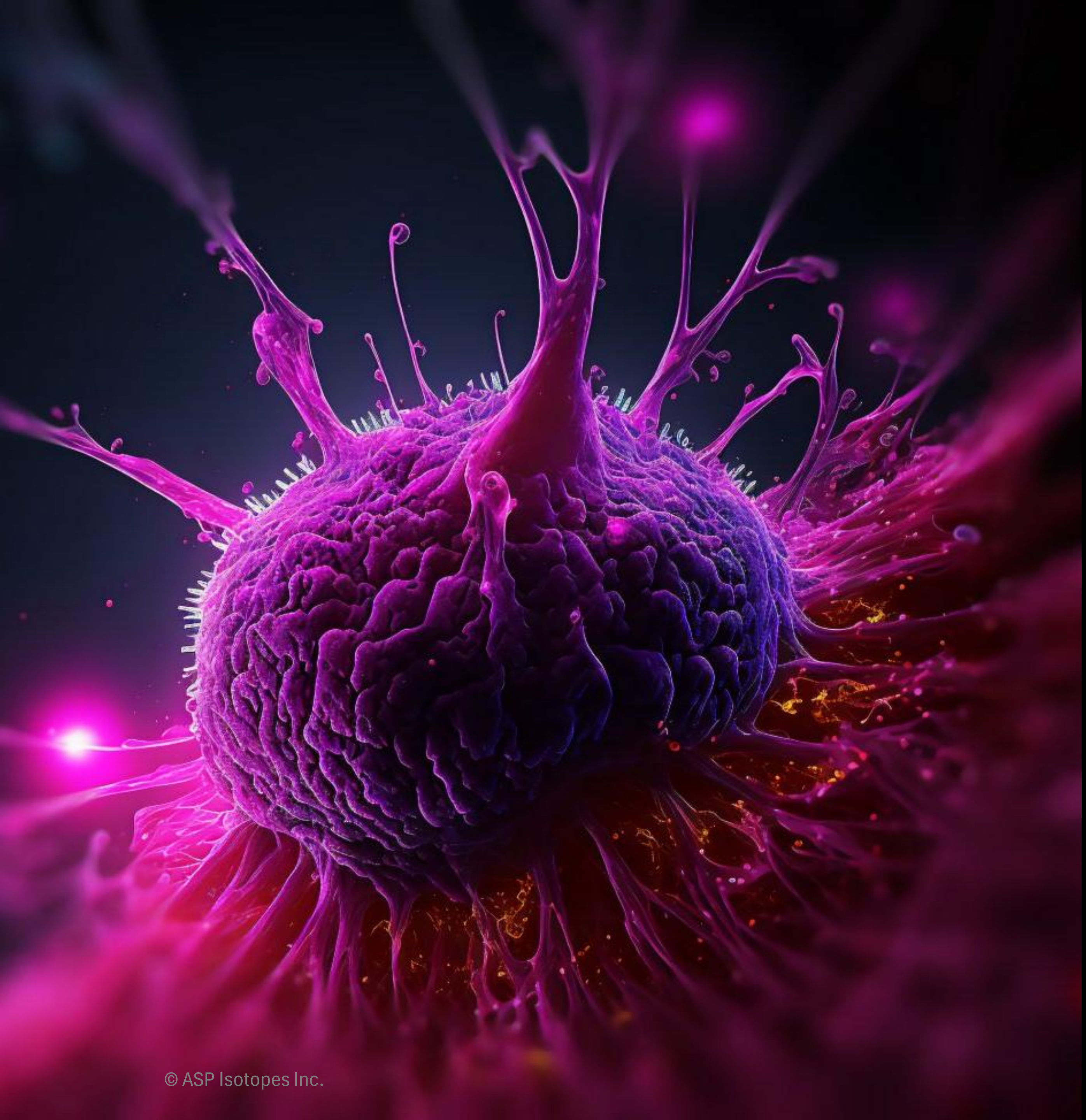
Short half-life Radioisotopes

End Market

Oncology Treatment

Non-Hodgkin lymphoma, Prostate Cancer, NETs

Neuroendocrine Tumors NETs



Cancer

18.5 million new cases
10.4 million deaths globally

The most common cancers are breast, lung, colorectal, prostate, and stomach

- World Health Organisation (2023 - 2024)

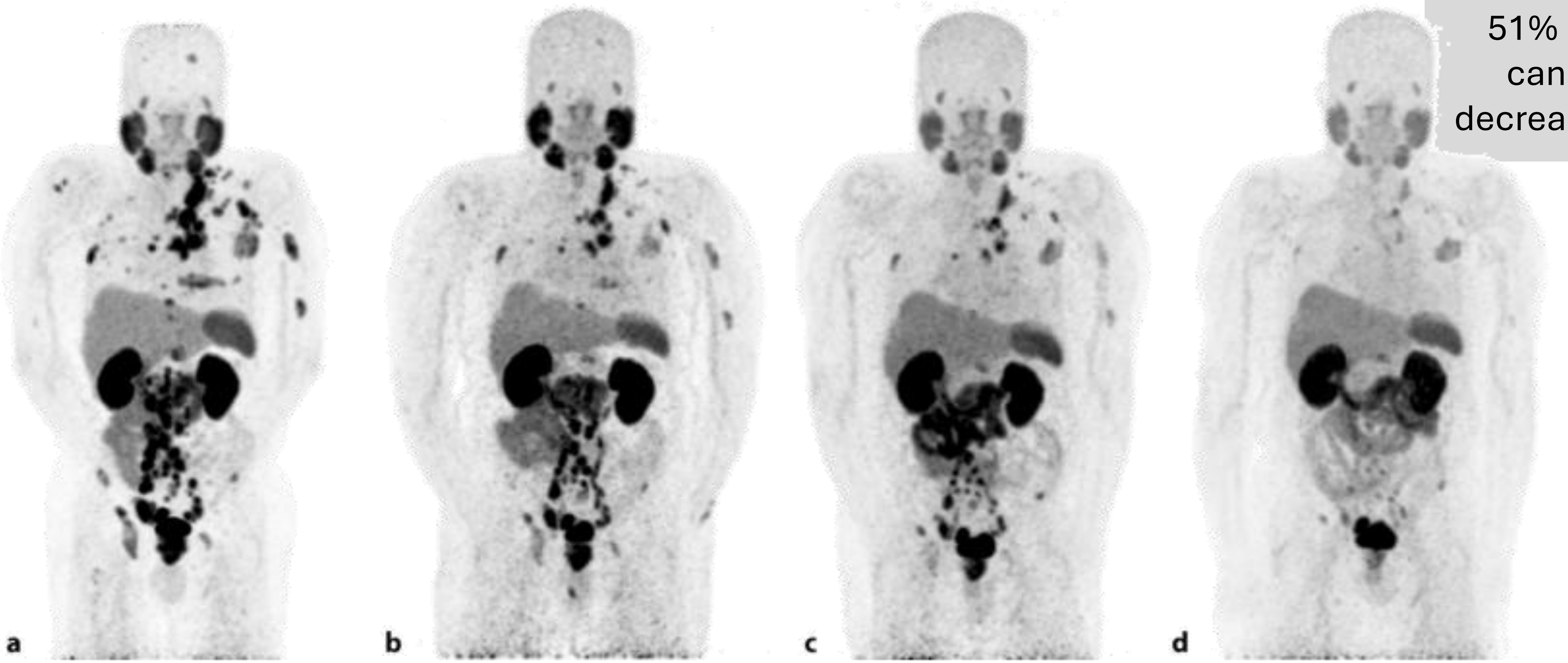
“ Prostate cancer is the <u>most</u> common male cancer globally and locally and showing significant increases.”

- Cancer Association of South Africa (CANSA, 2024)

Lu-177 : the newest revolutionary cancer treatment

75 % successful treatments

51% patients' cancer had decreased > 50 %



Baseline

After 2 cycles of treatment with 6.0 GBq [Lu-177] Lu-PSMA-167

After 4 cycles of treatment with 6.0 GBq [Lu-177] Lu-PSMA-167

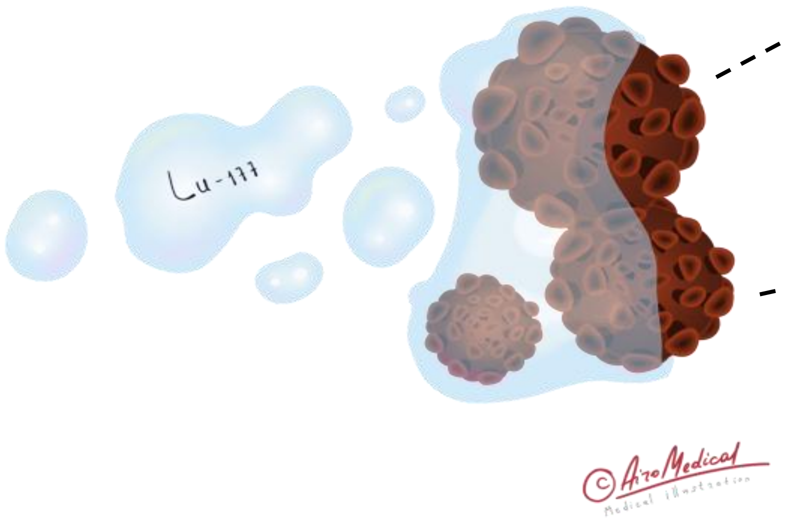
After 6 cycles of treatment with 6.0 GBq [Lu-177] Lu-PSMA-167

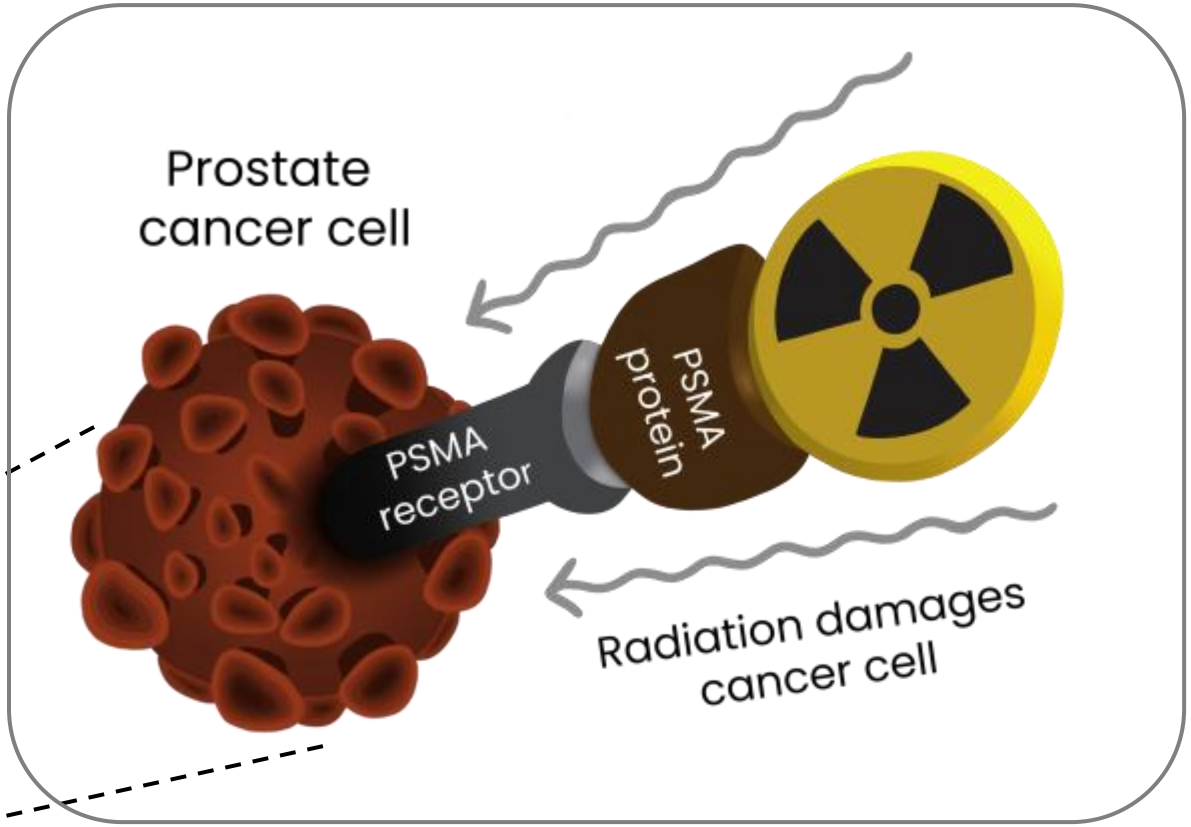
van Kalmthout, *et al.*
Tijdschr Urol **10**, 141–146 (2020)

Lu-177 is a precisely targeted cancer treatment

"... a microscopic, guided missile system designed to find and destroy prostate cancer cells"

- After an IV dose, the drug finds PSMA on prostate-cancer cells and is absorbed.
- Lu-177 releases short-range radiation that damages the tumor from within.





N. Volak, *et al.*
[online] AiroMedical (2025)

Lu-177 is comparable to other cancer treatments

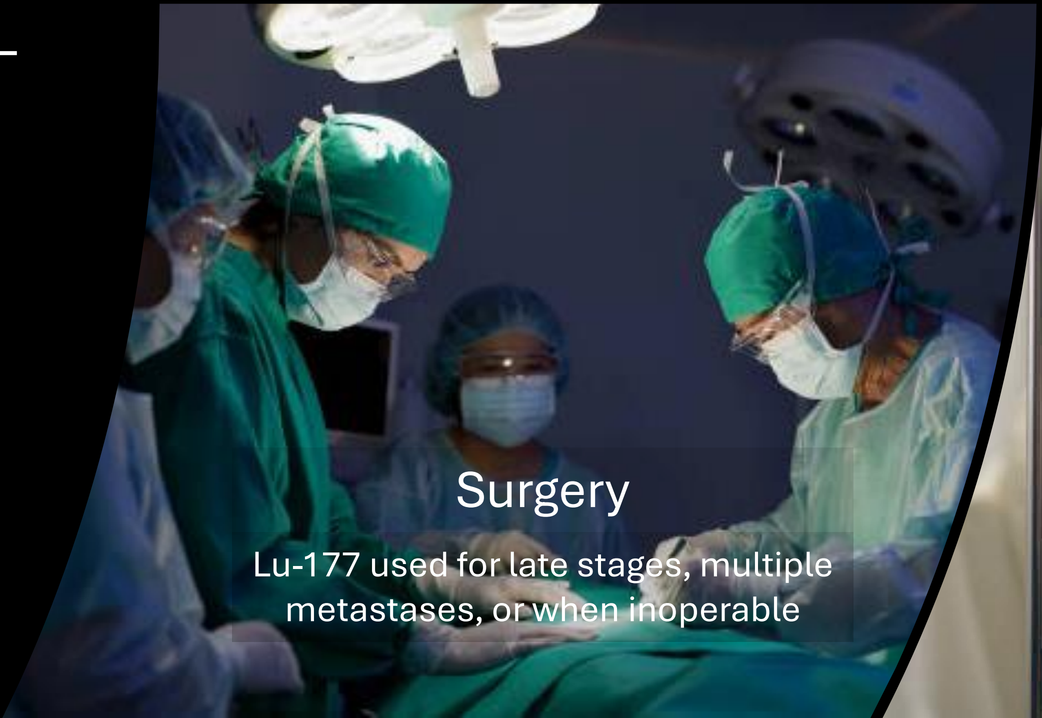
Precision without extensive damage (minimized side effects)

External radiation

Lu-177 treats multiple metastases at once

Immunotherapy

Lu-177 doesn't rely on immune response



Surgery

Lu-177 used for late stages, multiple metastases, or when inoperable

Chemotherapy

Lu-177 is more targeted & has less side effects

Lu-177 is traditionally produced from Lu- 176

Desired therapeutic isotope

$$^{176}Lu \xrightarrow{(n,\gamma)} {}^{177}Lu + {}^{177m}Lu$$

PET Labs

^{177}Lu: $t_{1/2}$ = 6.89 days

^{177m}Lu: $t_{1/2}$ = 160.4 days

When starting with Lu-176 an undesired radioactive impurity is made

Desired therapeutic isotope

$$^{176}\mathrm{Lu} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Lu} + {}^{177m}\mathrm{Lu}$$

$t_{½}$ = 6.89 days $t_{½}$ = 160.4 days

Undesired (isomer) radioactive impurity

"m" = metastable

Lu-177m isomer is an undesired impurity

- Similar to Lu-177 but in a high-energy "excited" state
- Longer half-life than stable Lu-177
- Can decay to stable Lu-177 (desired) <u>OR</u> Hf-177m (undesired) through β- decay

  - Additional separation needed
  - Handling & disposal issue

Ideally, we should make Lu-177 without the undesired isomer Lu-177m

Desired therapeutic isotope

$$^{176}Lu \xrightarrow{(n,\gamma)} {}^{177}Lu + \cancel{^{177m}Lu}$$

PET Labs

$t_{½}$ = 6.89 days

~~$t_{½}$ = 160.4 days~~

Undesired (isomer) radioactive impurity

"m" = metastable

Lu-177m isomer is an <u>undesired</u> impurity

Starting with Yb-176 produces Lu-177 without radioactive impurities

Traditional route starting with Lu-176

Desired therapeutic isotope

$$^{176}\mathrm{Lu} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Lu} + \cancel{^{177m}\mathrm{Lu}}$$

$t_{½}$ = 6.89 days ~~$t_{½}$ = 160.4 days~~

Does produce undesired isomer

Route starting with Yb-176

Desired therapeutic isotope

$$^{176}\mathrm{Yb} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Yb} \longrightarrow {}^{177}\mathrm{Lu}$$

$t_{½}$ = 1.9 hours $t_{½}$ = 6.89 days

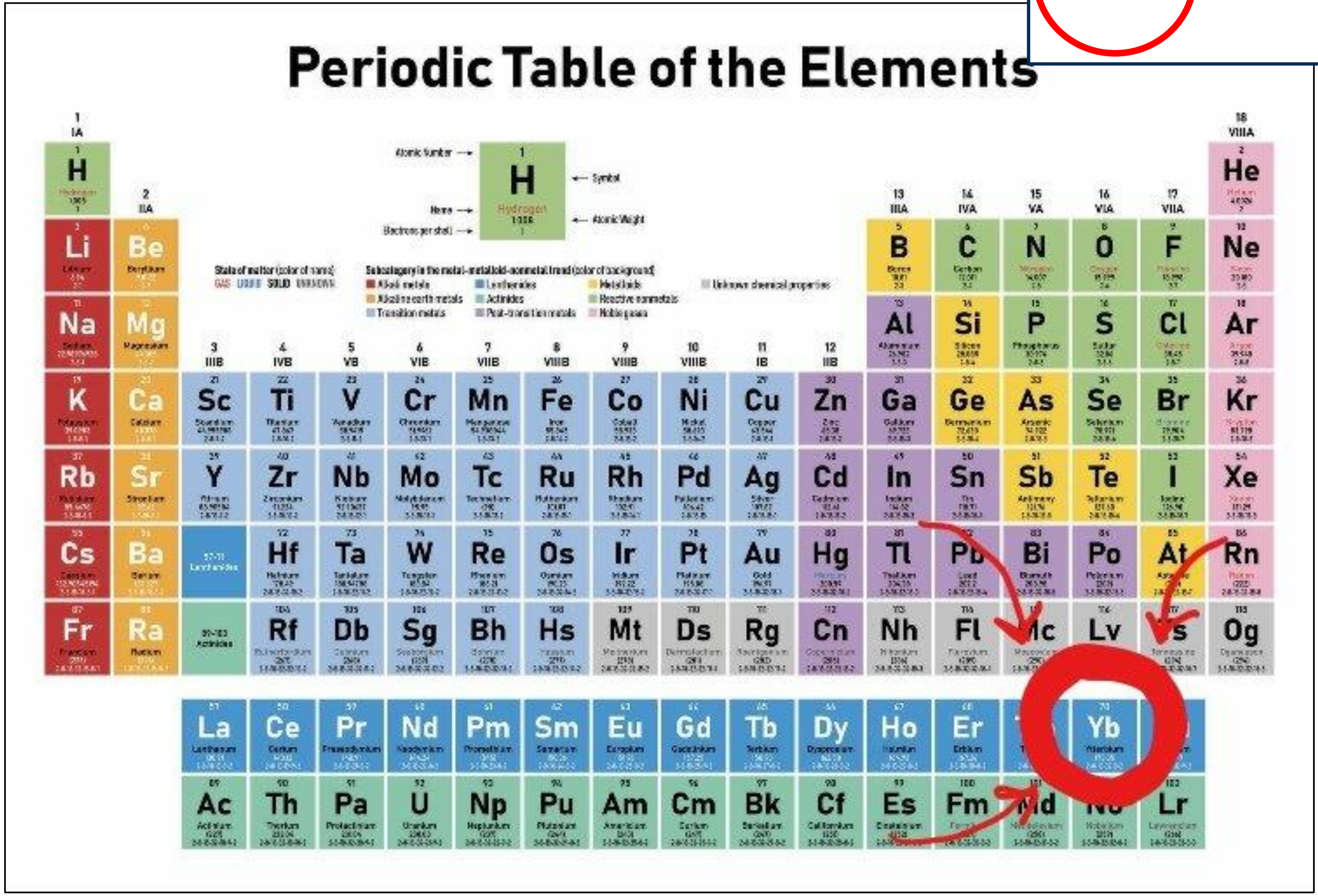
Does **NOT** produce undesired isomer

Yb-176 is an isotope of Yb, a rare-earth metal

$$^{176}\text{Yb} \xrightarrow{(n,\gamma)} {}^{177}\text{Yb} \longrightarrow {}^{177}\text{Lu}$$

^{177}Yb: $t_{1/2}$ = 1.9 hours

^{177}Lu: $t_{1/2}$ = 6.89 days



I'm rare

Yb-176 is found in Ytterbium metal

Yb-176 is an isotope of Yb, a rare-earth metal

$$^{176}\mathrm{Yb} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Yb} \longrightarrow {}^{177}\mathrm{Lu}$$

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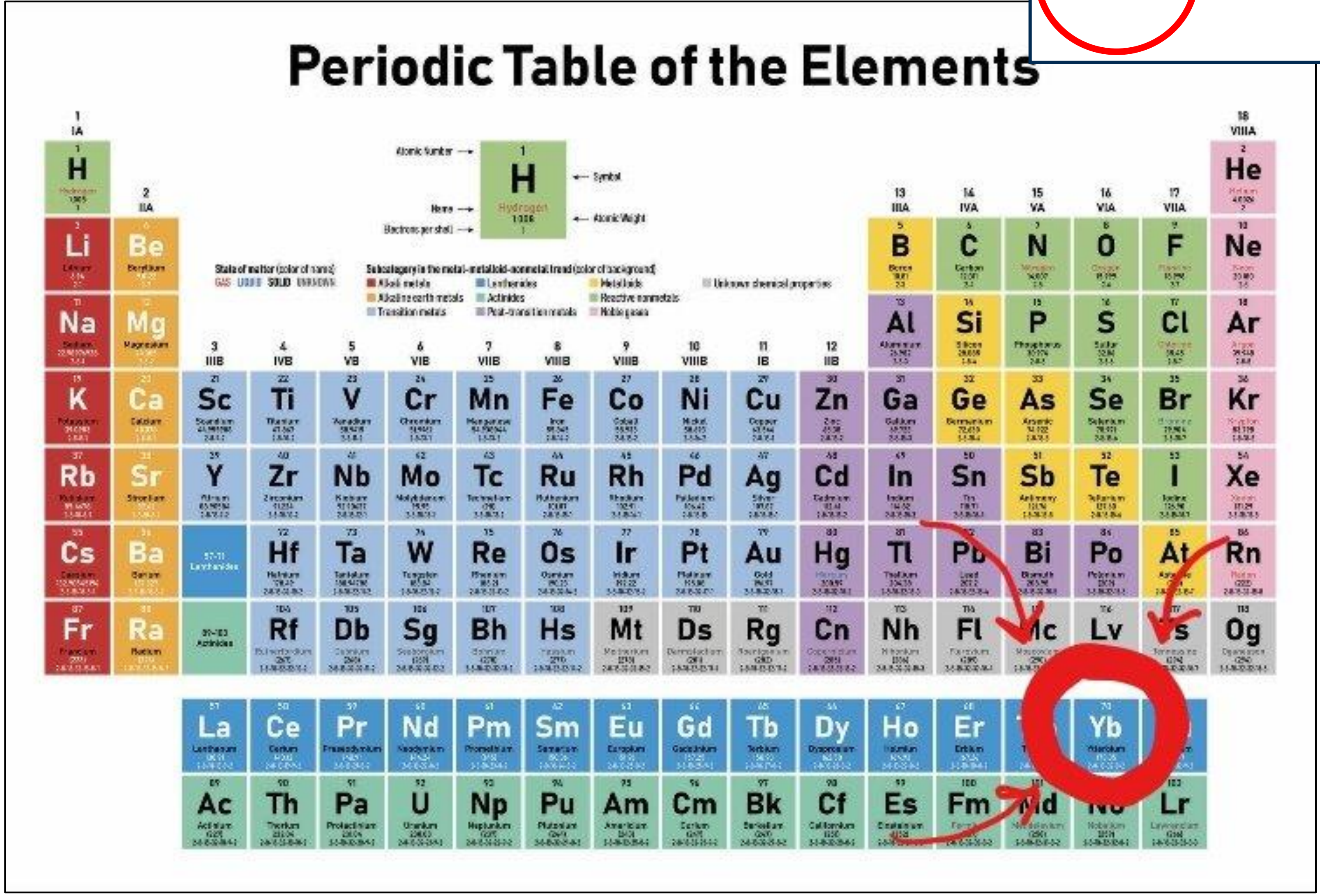
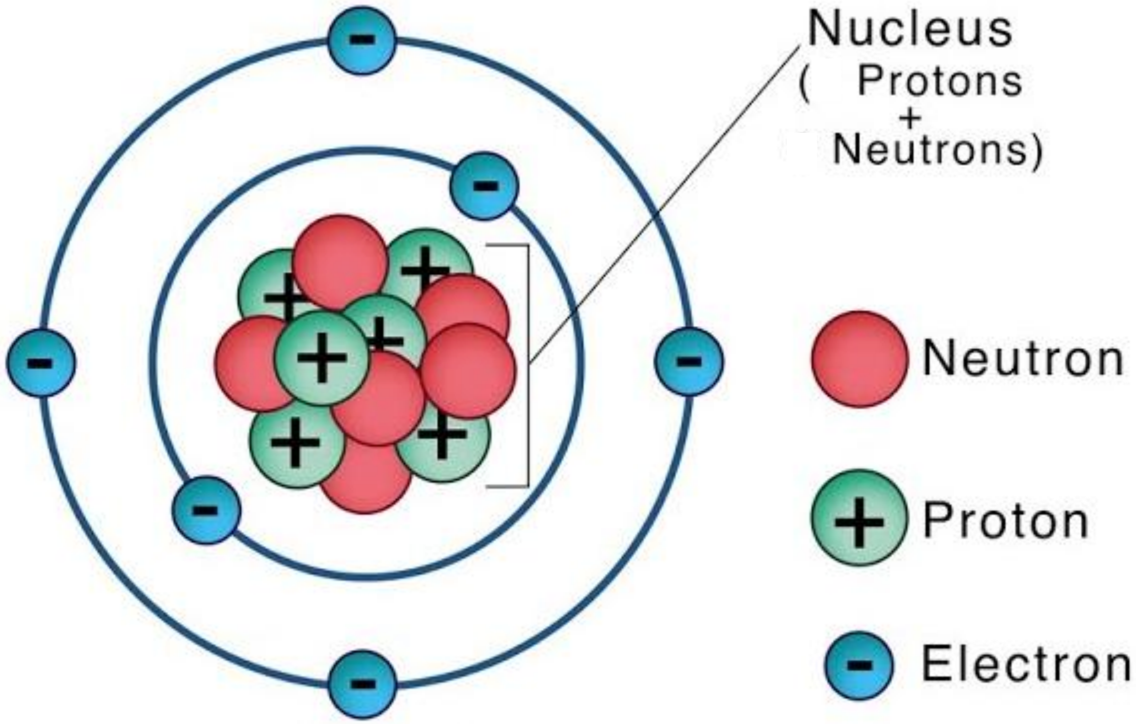


Yb-176 is found in Ytterbium metal

I'm rare

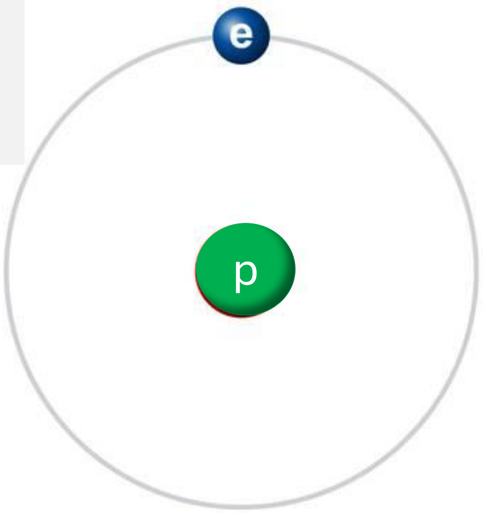
What is an ISOTOPE?

Atoms are the basic building blocks of matter



Isotopes are atoms of the same element with <u>different</u> nuclear masses

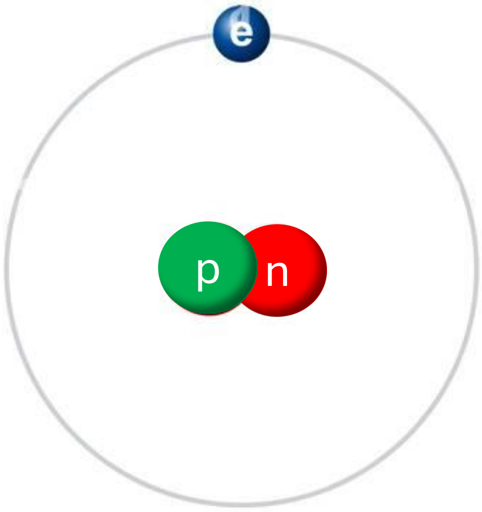
Let's use hydrogen for simplicity



$^{1}_{1}\mathrm{H}$

1 Proton
0 Neutrons
1 Electron

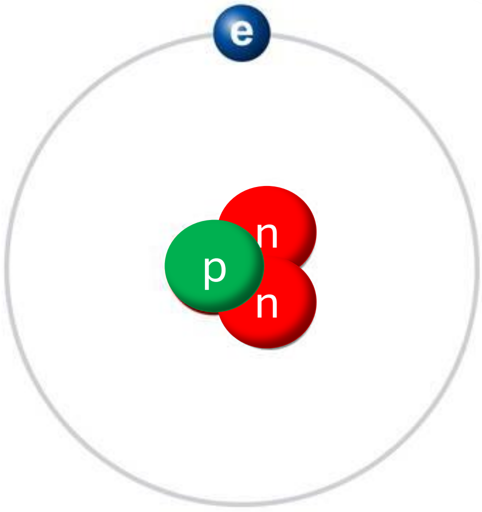
Natural abundance ~ **99.99 %**
Non- radioactive



$^{2}_{1}\mathrm{H}$

1 Proton
1 Neutrons
1 Electron

Natural abundance ~ **0.015 %**
Non- radioactive



$^{3}_{1}\mathrm{H}$

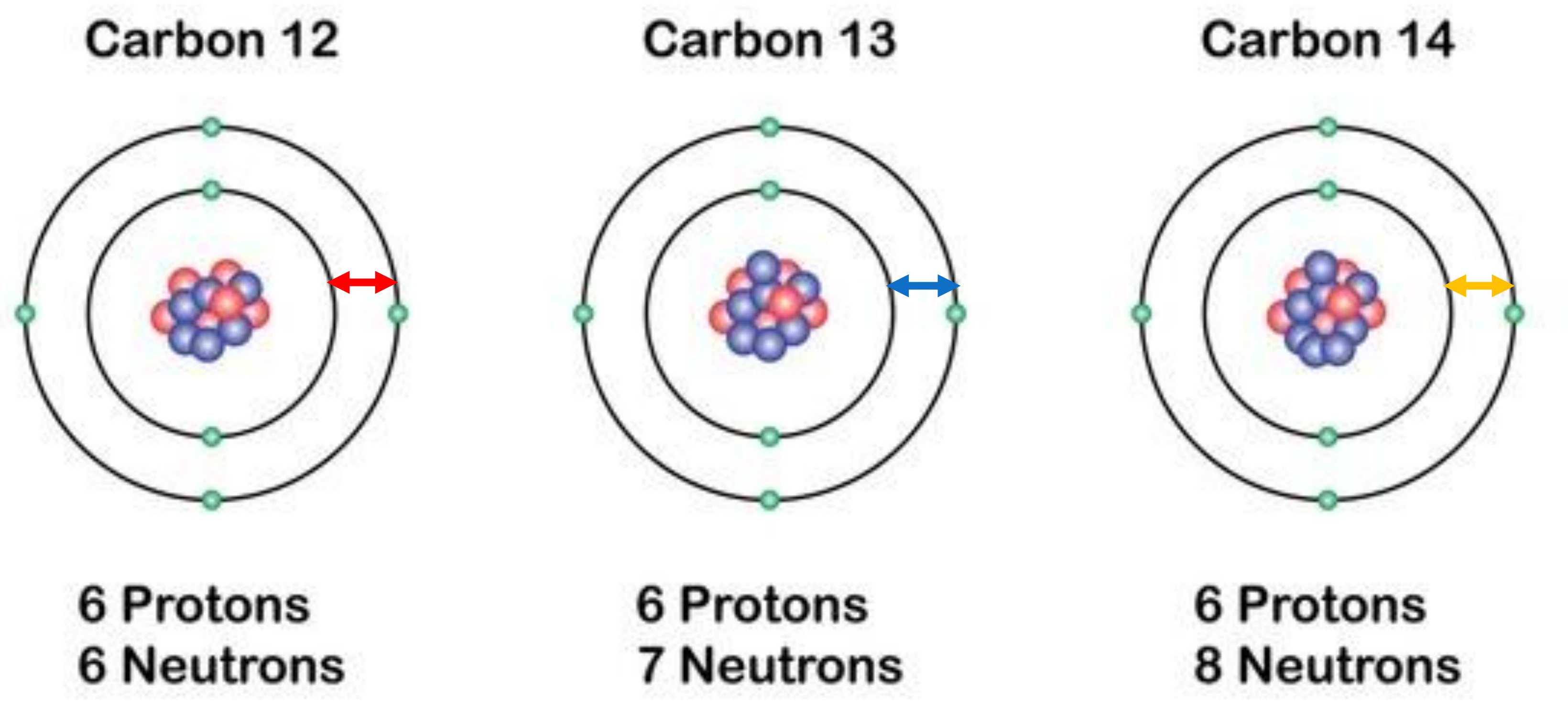
1 Proton
2 Neutrons
1 Electron

Natural abundance = **trace**
Radioactive

The nuclear masses & stability are different

Isotopes are atoms of the same element with <u>different</u> nuclear masses

Now, let's consider carbon...



The energy levels have <u>slightly</u> different energies

Isotopes are atoms of the same element with tiny differences in their atomic structures

“microscopic differences”

Different periodic elements

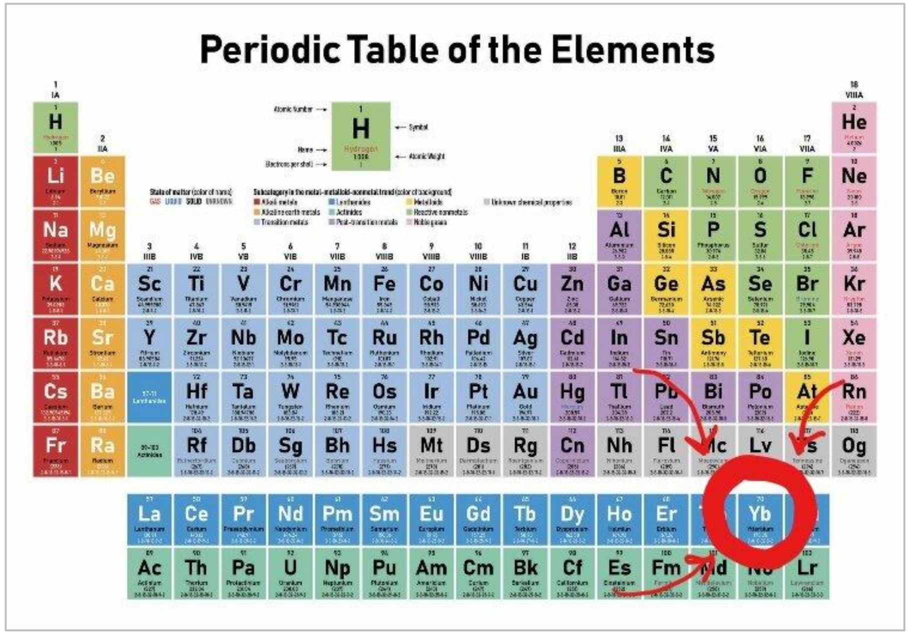
“quantum differences”

Different isotopes

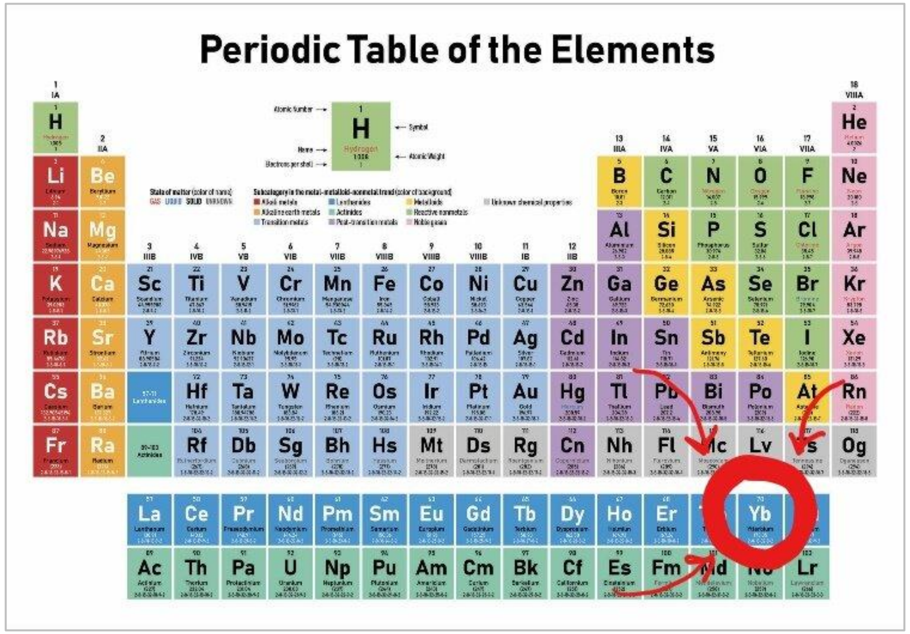
Ytterbium (Yb) has x7 stable isotopes

Yb (natural)

Yb - 168	Yb- 170	Yb- 171	Yb- 172	Yb- 173	Yb- 174	Yb- 176
# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70
# n^0 = 98	# n^0 = 100	# n^0 = 101	# n^0 = 102	# n^0 = 103	# n^0 = 104	# n^0 = 105
Abundance ~ **0.12 %**	Abundance ~ **2.98 %**	Abundance ~ **14.09 %**	Abundance ~ **21.68 %**	Abundance ~ **16.10 %**	Abundance ~ **32.03 %**	Abundance ~ **13.00 %**



Yb-176 is one of the x7 stable isotopes



Yb (natural)

Yb - 168	Yb- 170	Yb- 171	Yb- 172	Yb- 173	Yb- 174	Yb- 176
# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70	# p^+ = 70
# n^0 = 98	# n^0 = 100	# n^0 = 101	# n^0 = 102	# n^0 = 103	# n^0 = 104	# n^0 = 105
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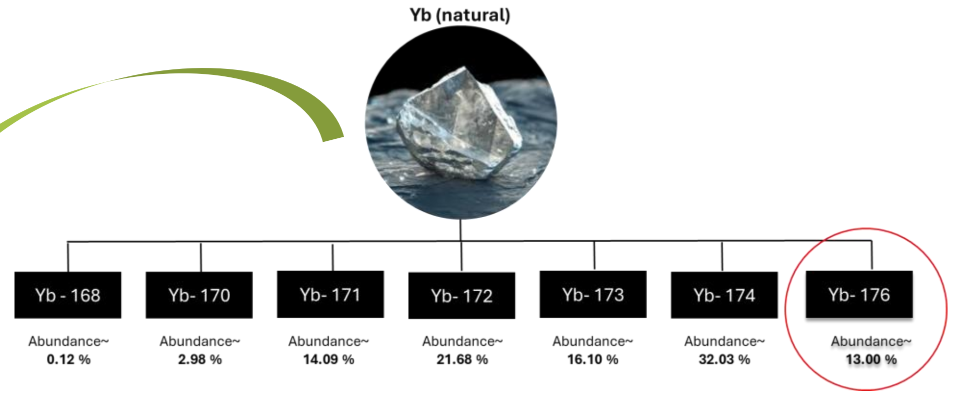
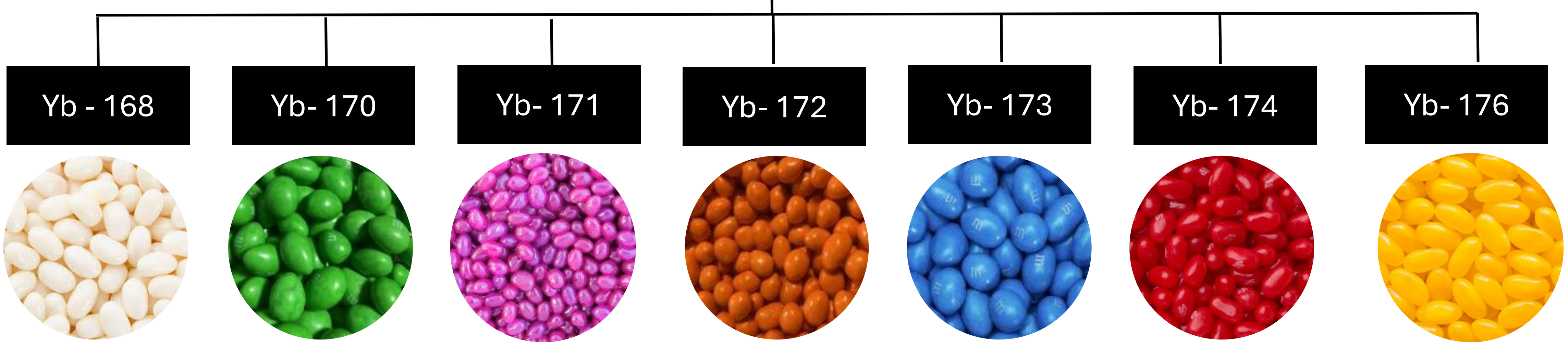
Think of Yb as a packet of jelly beans...

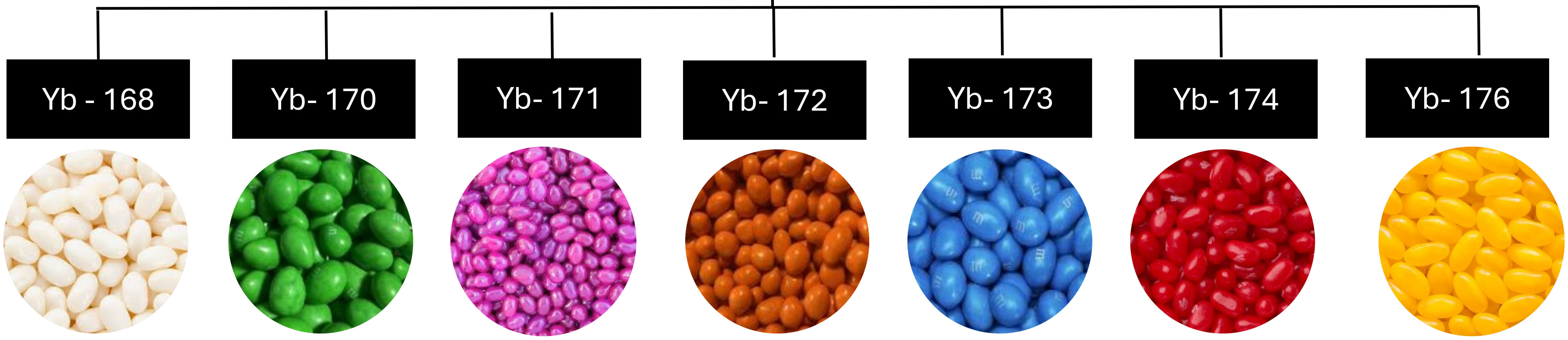




Think of Yb as a packet of jelly beans...

Yb (natural)

Jelly beans are the similar but not identical - different colours.



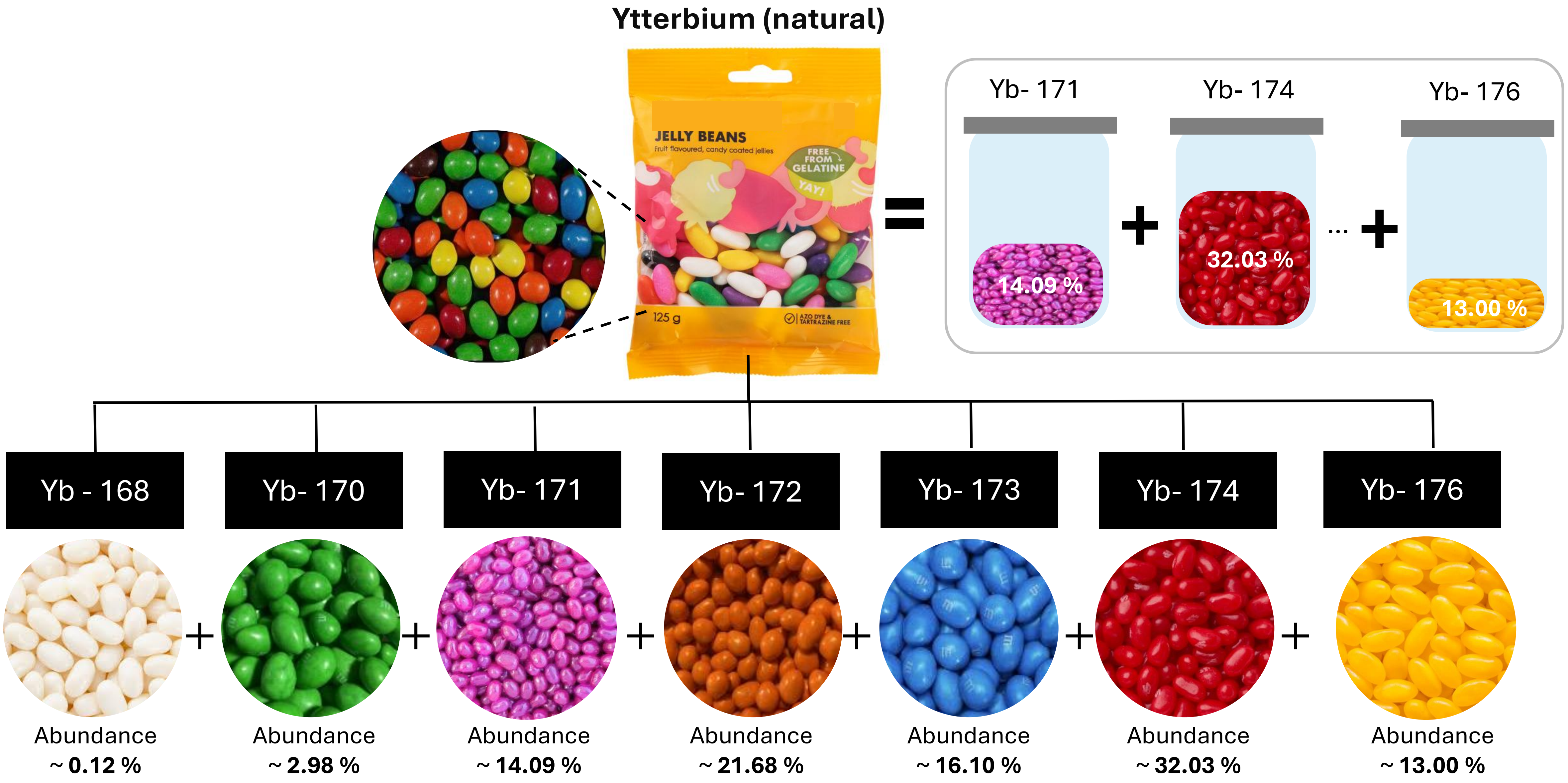
Some colours are more than others...

Yb (natural)

Jelly bean colours are present in different ratios

Yb - 168	Yb- 170	Yb- 171	Yb- 172	Yb- 173	Yb- 174	Yb- 176
						
Abundance **~ 0.12 %**	Abundance **~ 2.98 %**	Abundance **~ 14.09 %**	Abundance **~ 21.68 %**	Abundance **~ 16.10 %**	Abundance **~ 32.03 %**	Abundance **~ 13.00 %**

But, together make up the entire bag



We need the yellow jelly beans for Lu-177

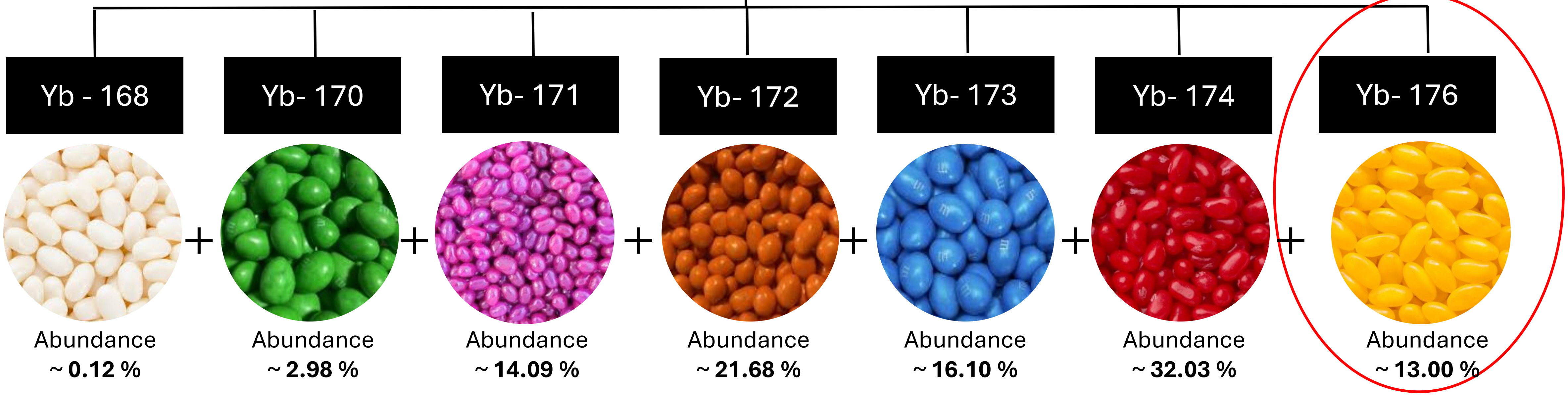
Ytterbium (natural)

Desired therapeutic isotope

$^{176}Yb \xrightarrow{(n,\gamma)} {}^{177}Yb \longrightarrow {}^{177}Lu$

^{177}Yb: $t_{½}$ = 1.9 hours

^{177}Lu: $t_{½}$ = 6.89 days



ONLY the yellow jelly beans for Lu-177

Ytterbium (natural)

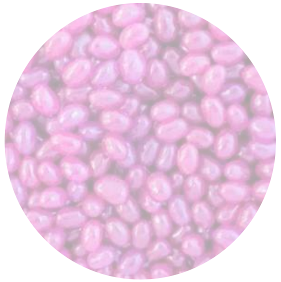
Other jelly beans taste '*yucky*'

Desired therapeutic isotope

$$ {}^{176}\mathrm{Yb} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Yb} \longrightarrow {}^{177}\mathrm{Lu} $$

^{177}Yb: $t_{1/2}$ = 1.9 hours

^{177}Lu: $t_{1/2}$ = 6.89 days

Yb - 168	Yb- 170	Yb- 171	Yb- 172	Yb- 173	Yb- 174	Yb- 176
	+ 	+ 	+ 	+ 	+ 	+ 
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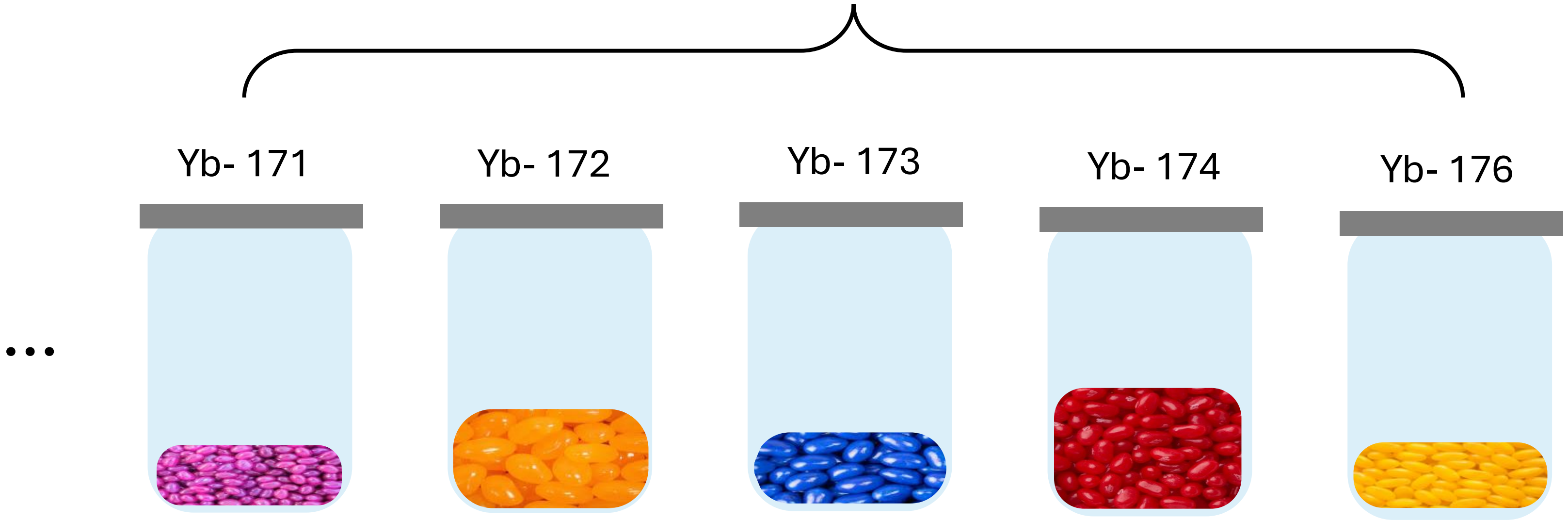
We need to separate the yellow jelly beans

Ytterbium (natural)

Desired therapeutic isotope

$$^{176}\mathrm{Yb} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Yb} \longrightarrow {}^{177}\mathrm{Lu}$$

$^{177}\mathrm{Yb}$: $t_{1/2}$ = 1.9 hours; $^{177}\mathrm{Lu}$: $t_{1/2}$ = 6.89 days



We need to isolate the yellow jelly beans

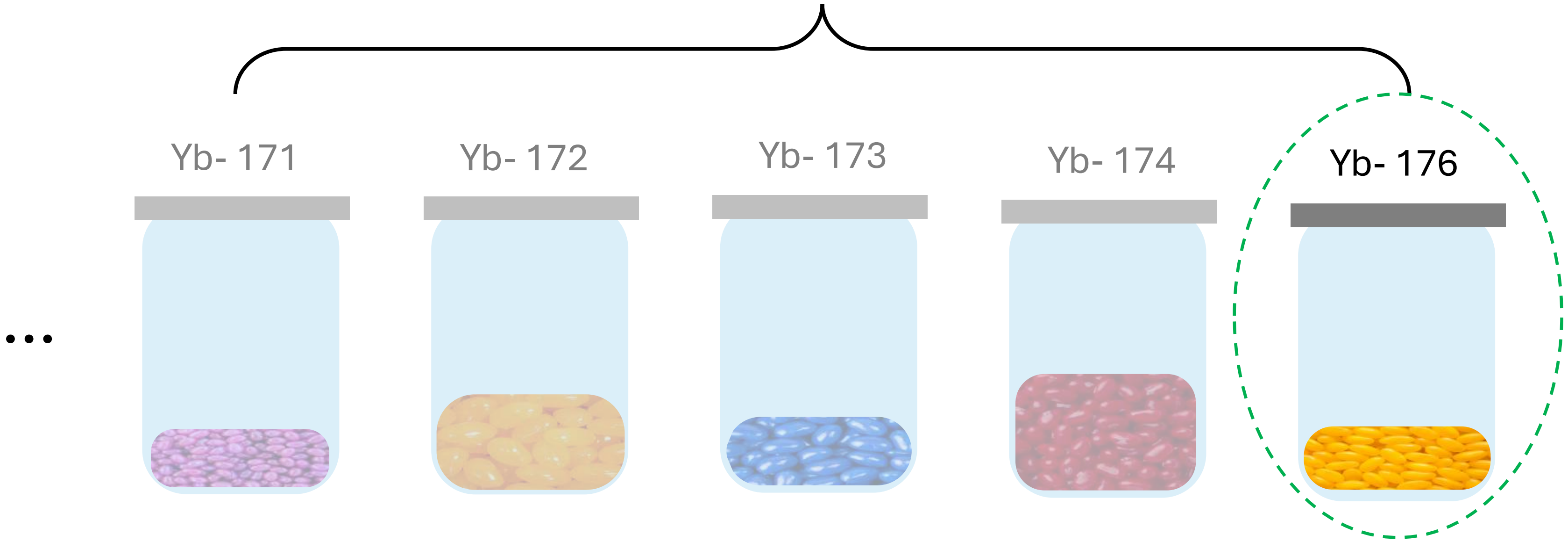
Ytterbium (natural)

Desired therapeutic isotope

$^{176}\mathrm{Yb} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Yb} \longrightarrow {}^{177}\mathrm{Lu}$

$^{177}\mathrm{Yb}$: $t_{½}$ = 1.9 hours

$^{177}\mathrm{Lu}$: $t_{½}$ = 6.89 days



We need to isolate the yellow jelly beans with high "selectivity"

Ytterbium (natural)

Desired therapeutic isotope

$$^{176}\mathrm{Yb} \xrightarrow{(n,\gamma)} {}^{177}\mathrm{Yb} \longrightarrow {}^{177}\mathrm{Lu}$$

^{177}Yb: $t_{½}$ = 1.9 hours

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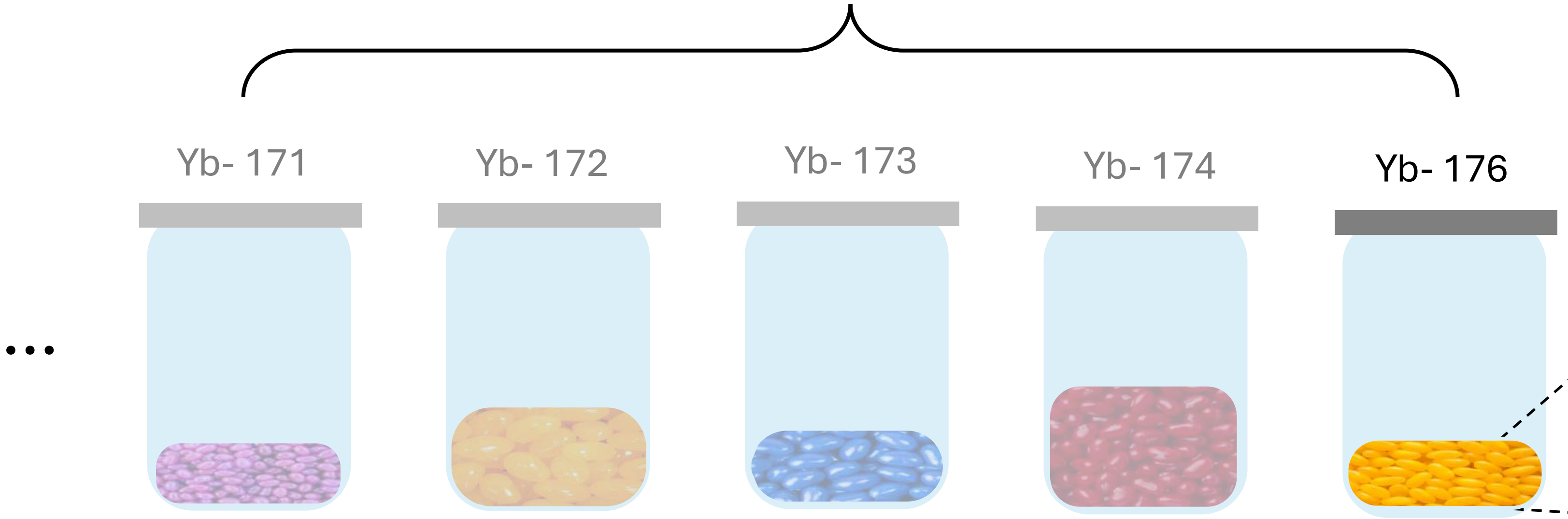
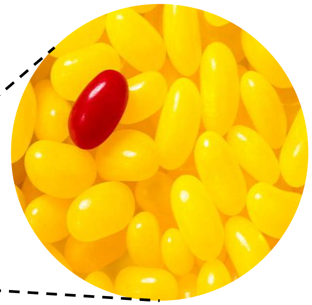
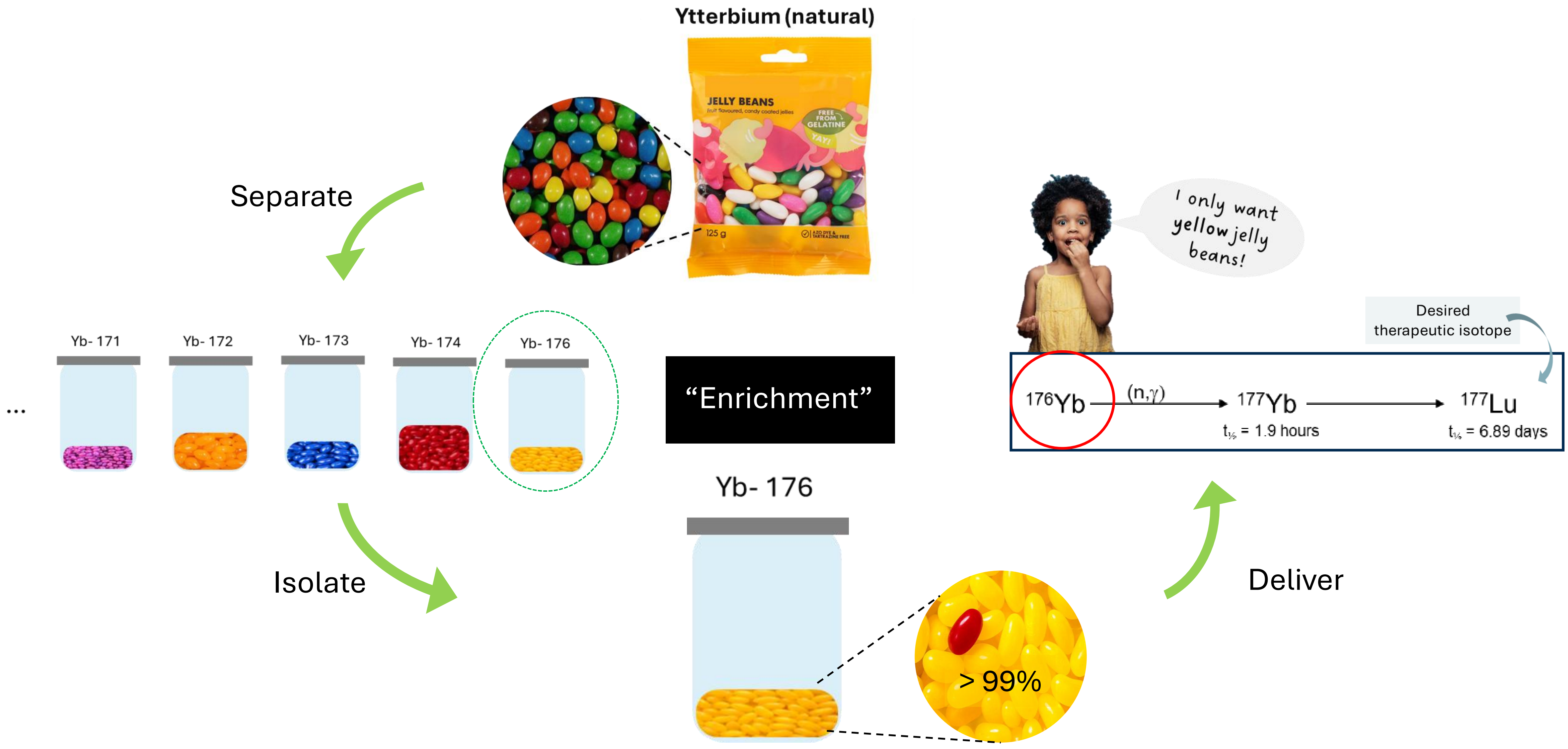


> 99 % of the jar should contain yellow jelly beans

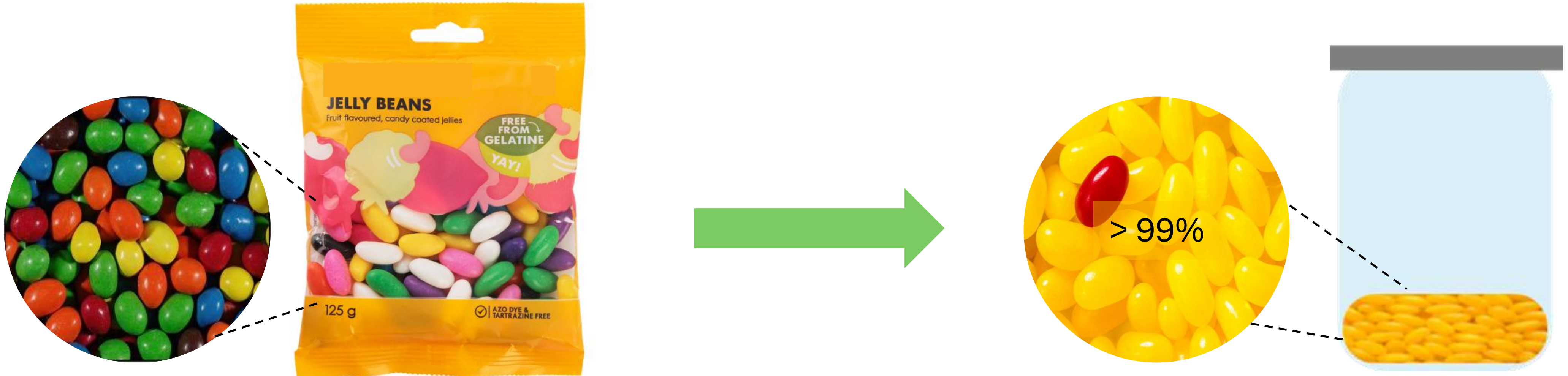


Once we have high-purity Yb-176, we can use it to make Lu-177



Back to reality...

Back to reality…

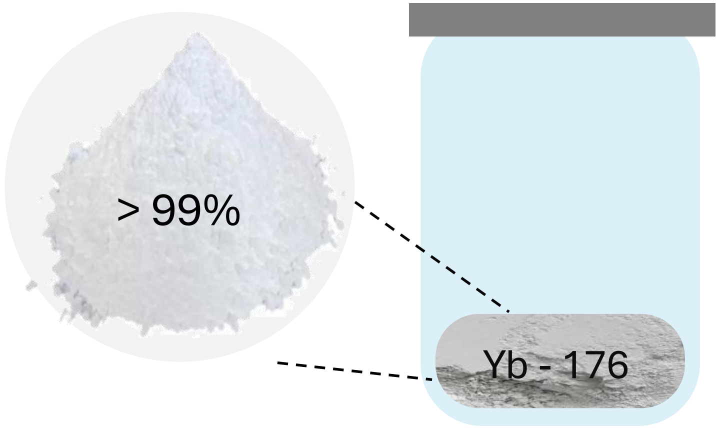


“Enrichment”

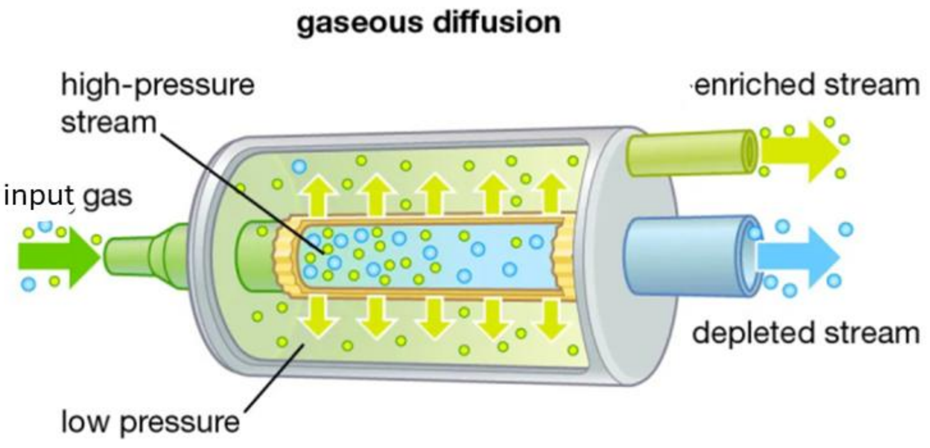
Yb-171
Yb-172
Yb-173
Yb-174
Yb-175
Yb-176
Yb-168
Yb-170

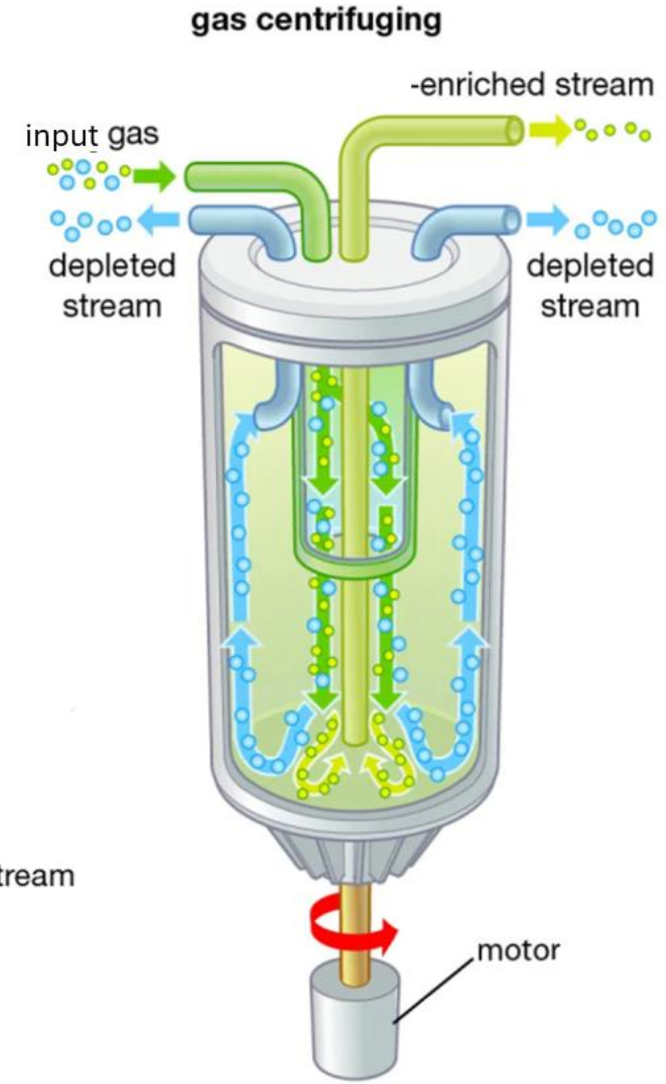
Natural Yb

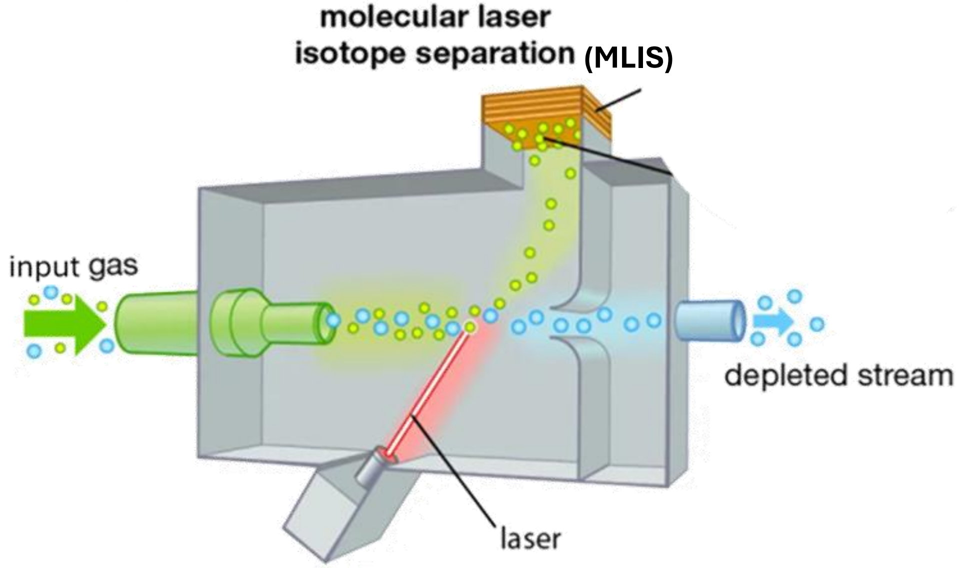
How do we do this in reality?

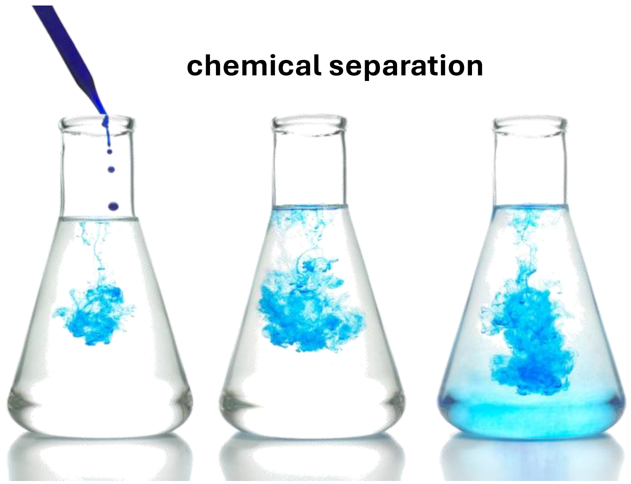


Various enrichment techniques exist

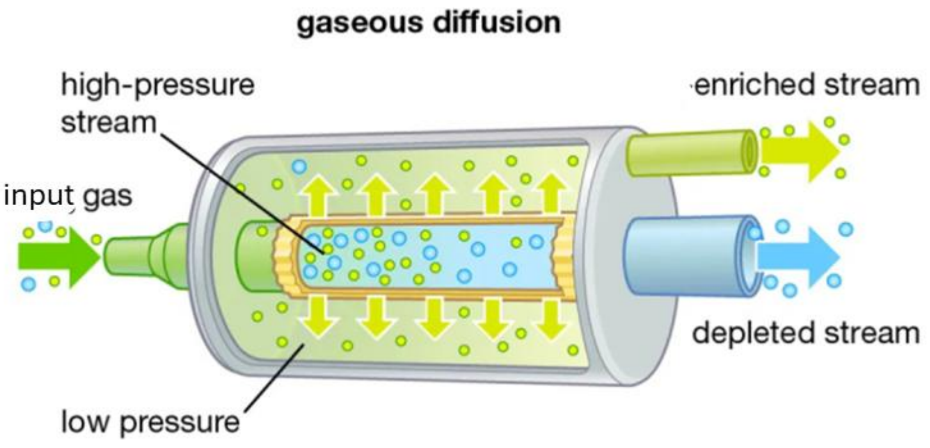


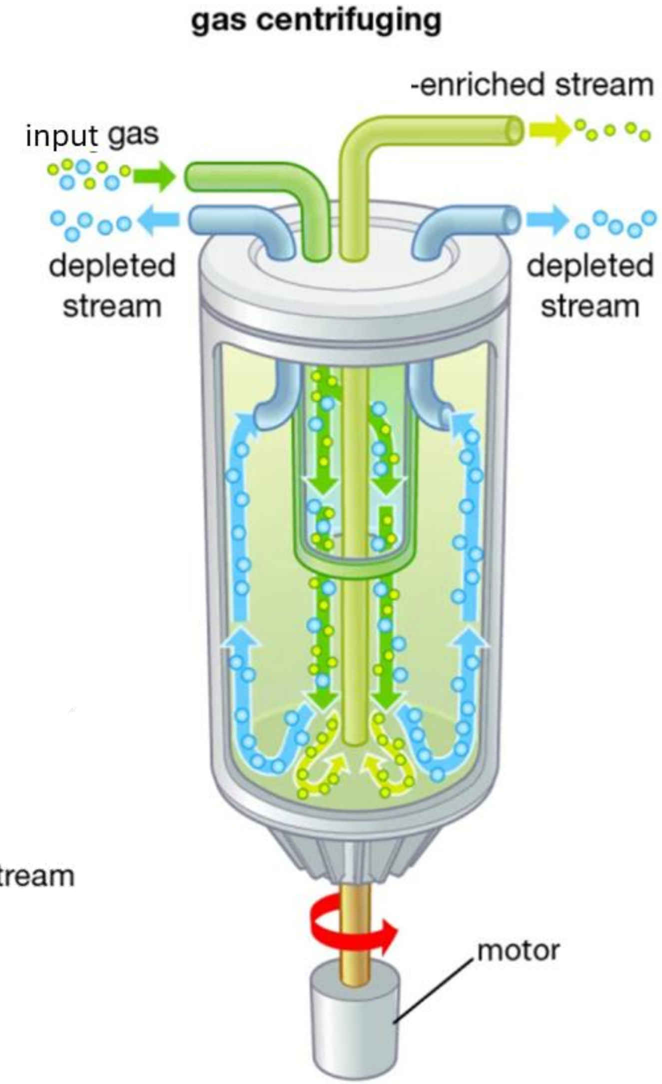


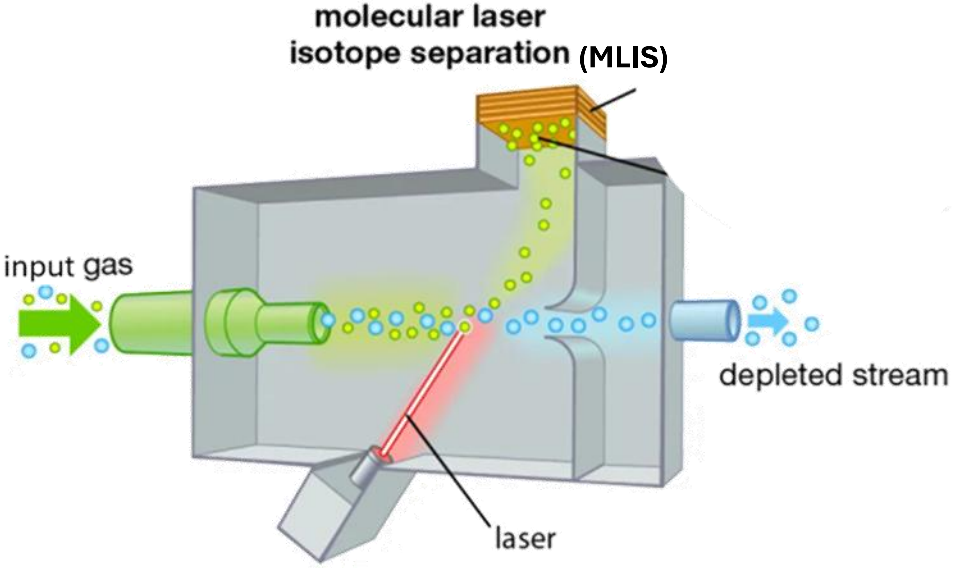




But they're not suitable for Yb-176 enrichment & production







Gaseous diffusion & centrifuge:

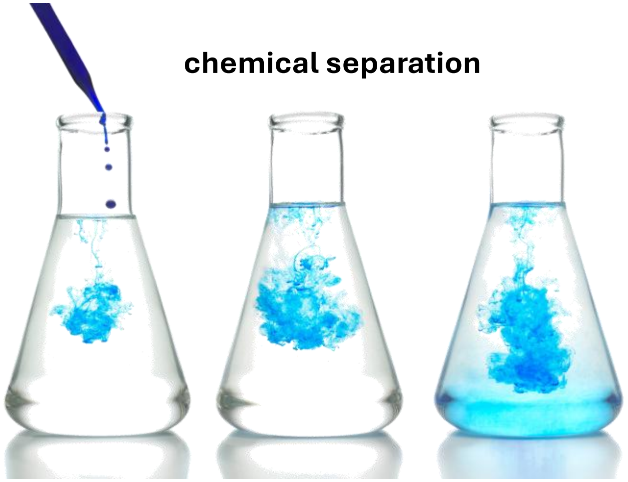
- No stable gas compound of Yb
- Chemically unstable
- Requires many stages

MLIS:

- Relies on molecular transitions
- No suitable, stable Yb molecule
- Not selective enough

Chemical separation:

- Lanthanides (Yb) very small chemical effects
- Not selective enough



We must resort to quantum techniques

"working with the smallest discrete units of energy or matter"

photons (p+)

electrons (e-)

quantum of energy

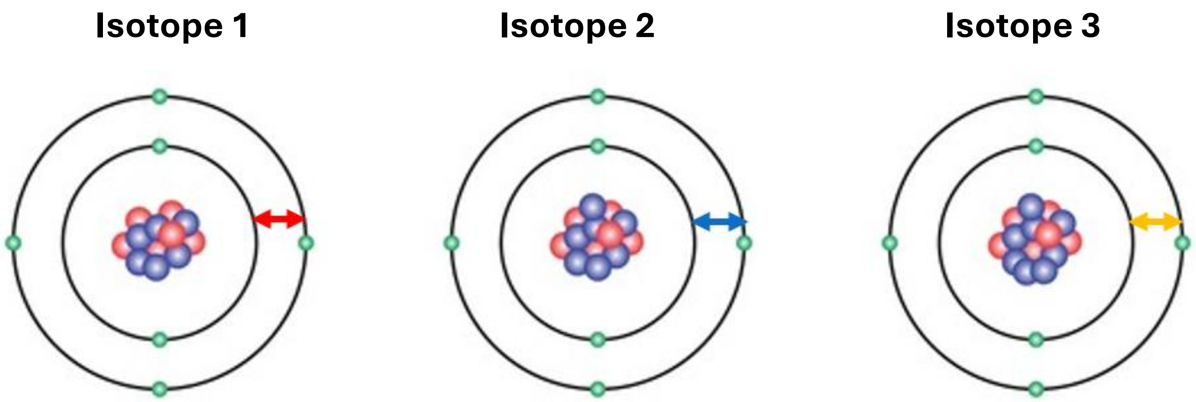
Isotopes like Yb have differences on the “quantum” level

Remains the same:

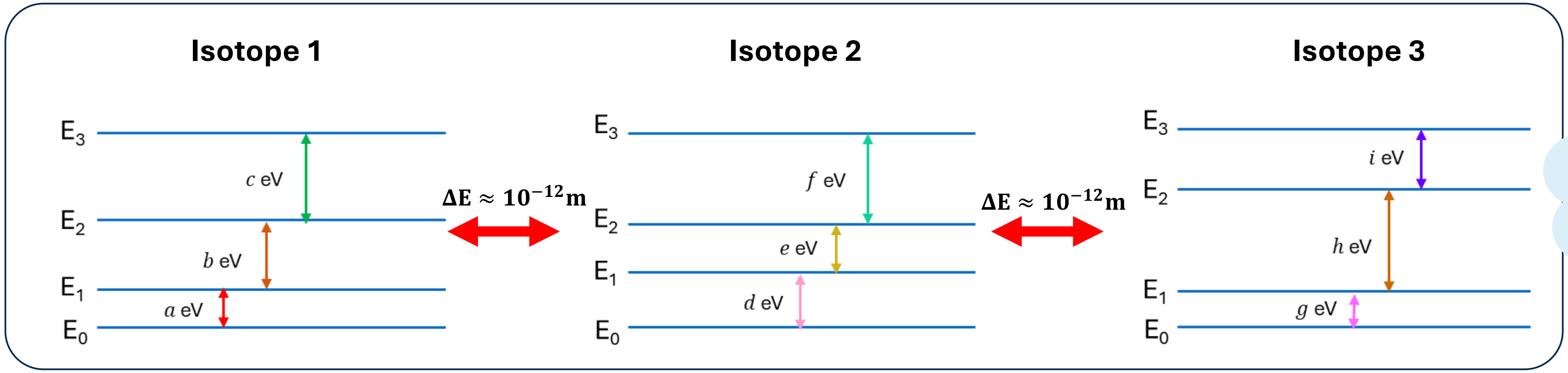
- # of protons → same chemical identity (element)
- # of electrons → same chemical reactions

Changes:

- # of neutrons
    - Nuclear stability → different decays
    - Energy levels → slight energy differences (gap)



“quantum differences”



Isotopes have unique “quantum fingerprints”

We can separate isotopes like Yb using their "quantum fingerprints"

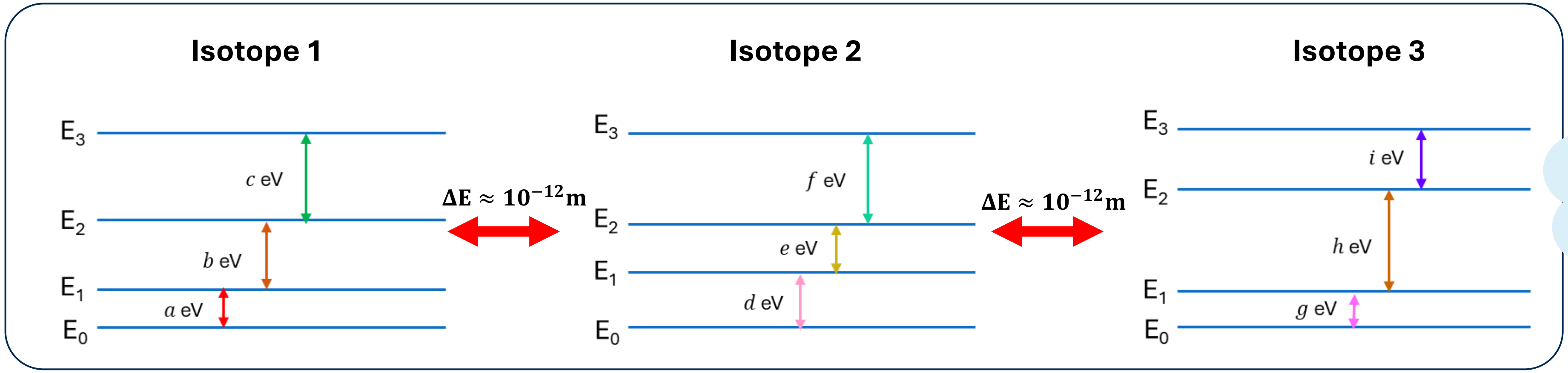
Remains the same:

- # of protons → same chemical identity (element)
- # of electrons → same chemical reactions

Changes:

- # of neutrons
  - Nuclear stability → different decays
  - Energy levels → slight energy differences (gap)

Identify & separate isotopes using their "quantum fingerprints"



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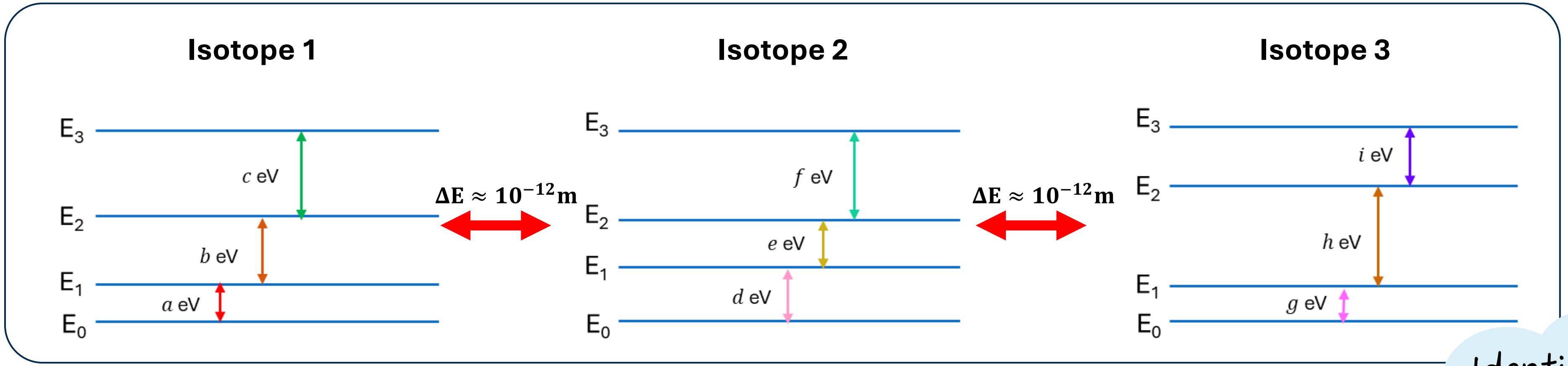
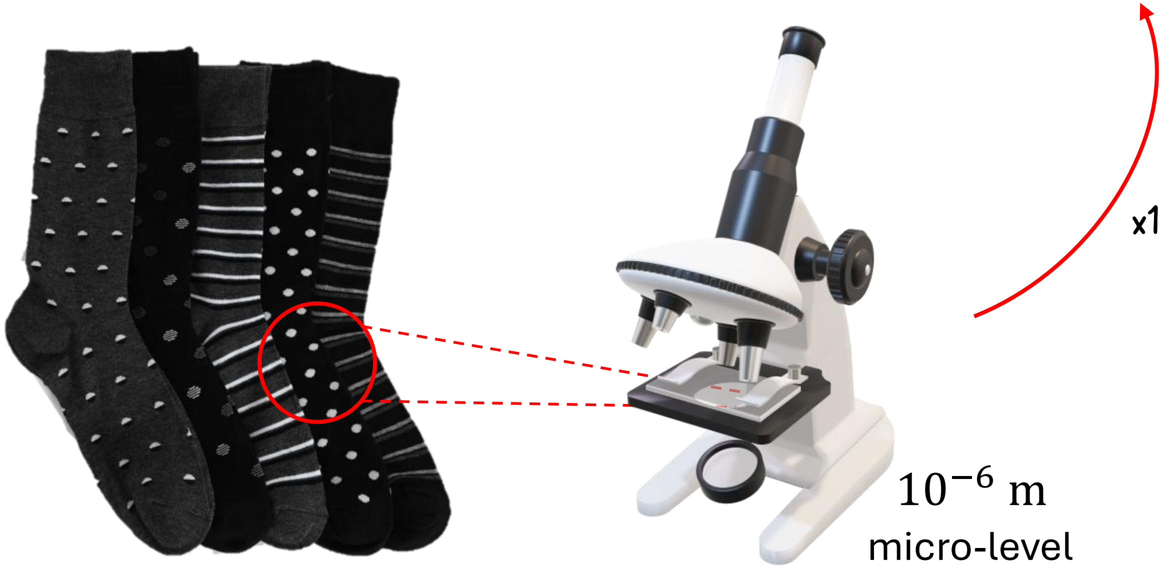


Identify & separate isotopes using their “quantum fingerprints”

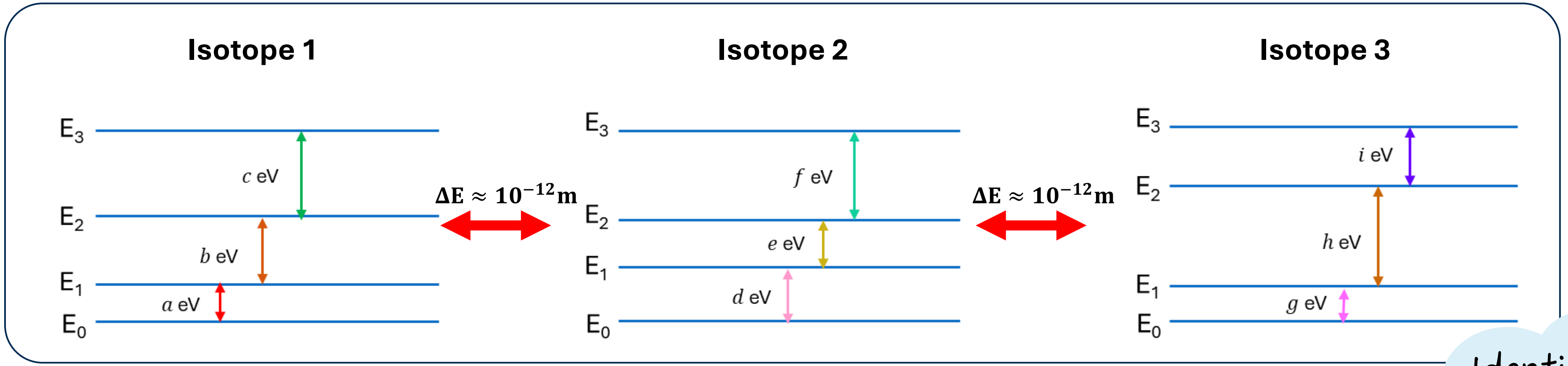
10^{-12} m
pico-level

x1000 smaller



10^{-6} m
micro-level

We can separate isotopes like Yb using their “quantum fingerprints”



Identify & separate isotopes using their “quantum fingerprints”

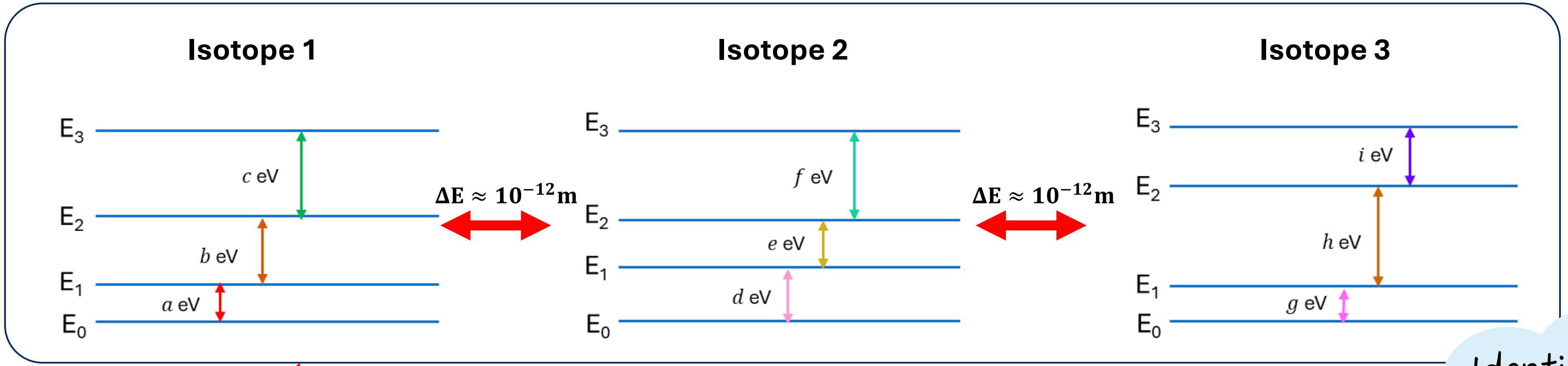
10^{-12} m
pico-level

x1000 smaller

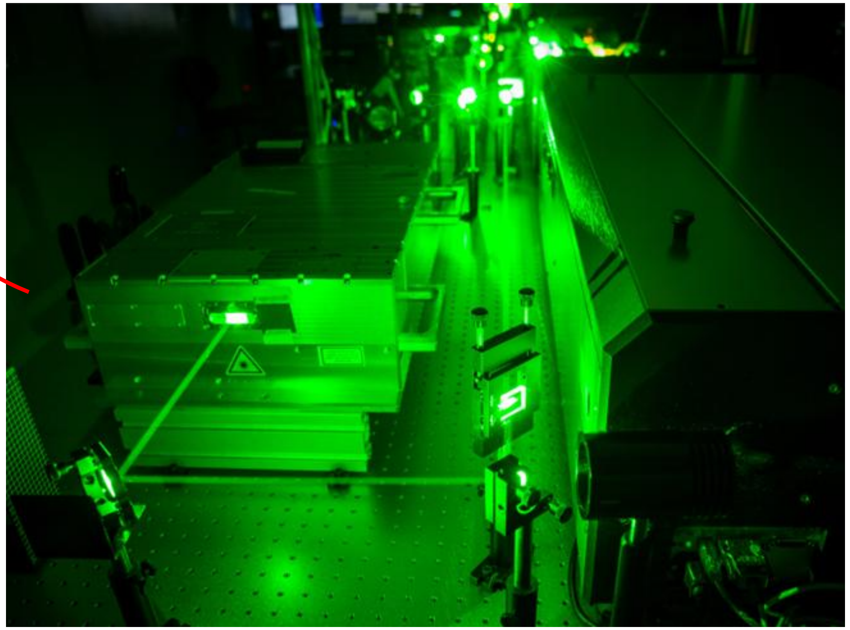
10^{-6} m
micro-level

How can we exploit these picometer differences in energy levels?

We can use lasers to select isotopes on a picometer level



10^{-12} m
pico-level

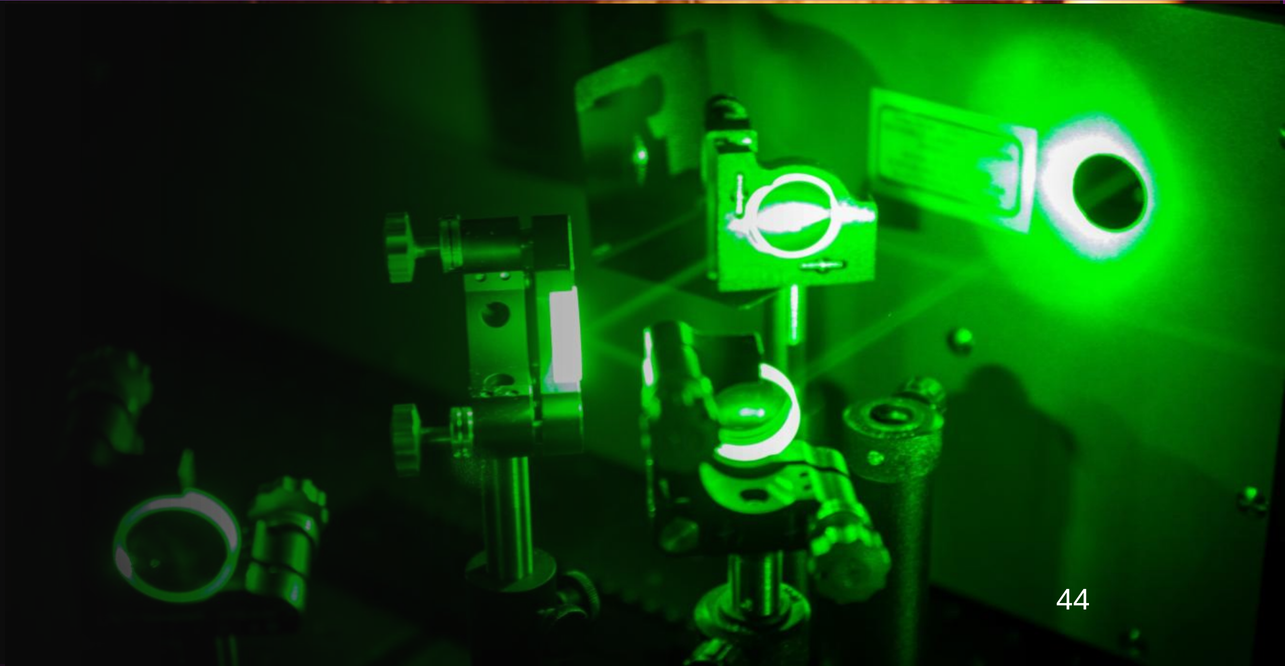


Identify & separate isotopes using their "quantum fingerprints"

How can we exploit these picometer differences in energy levels?

What is *'Quantum Enrichment'* ?

Rare earth metal 'refining' with lasers

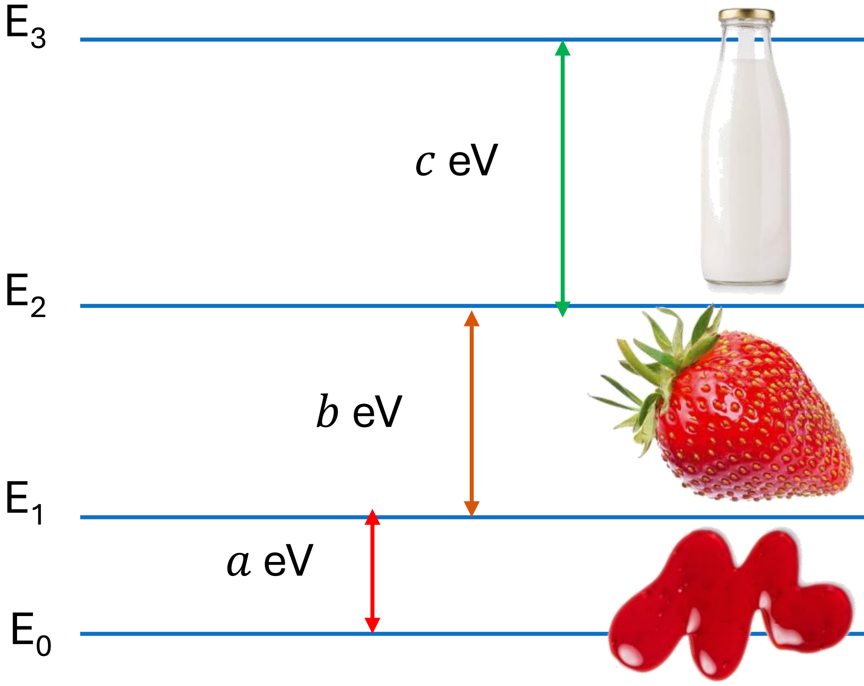


Each isotope has its favourite 'milkshake'

- Similar ingredients, but there are small differences that make it special
- Milkshakes have to made in a very specific way
- Isotopes are 'allergic' and dislike ingredients in other milkshakes
- Having enough milkshake gives the isotope a 'sugar rush'

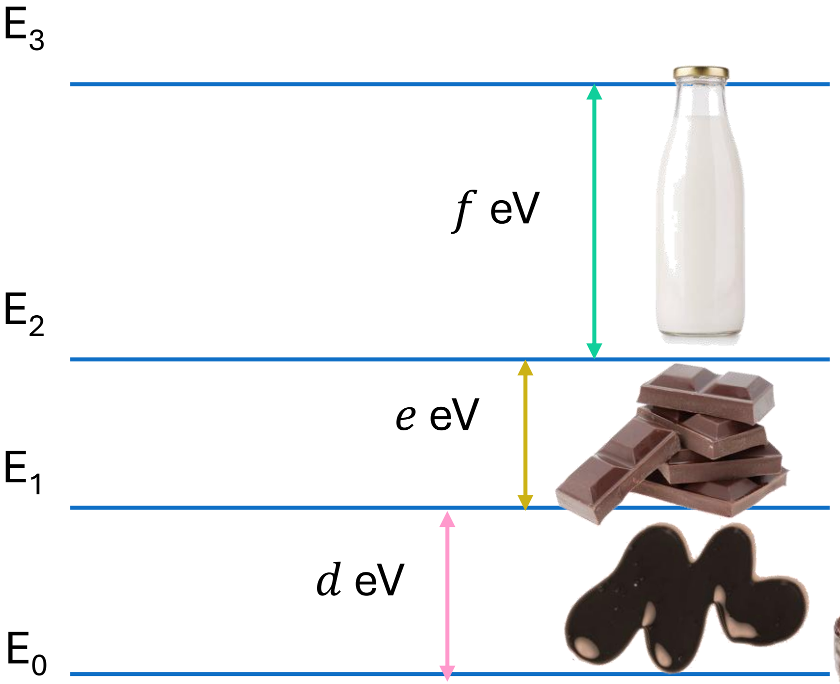
Each isotope has its unique energy levels or ‘ingredients’

Isotope (1)



We have to use the correct “ingredients” to get a strawberry milkshake

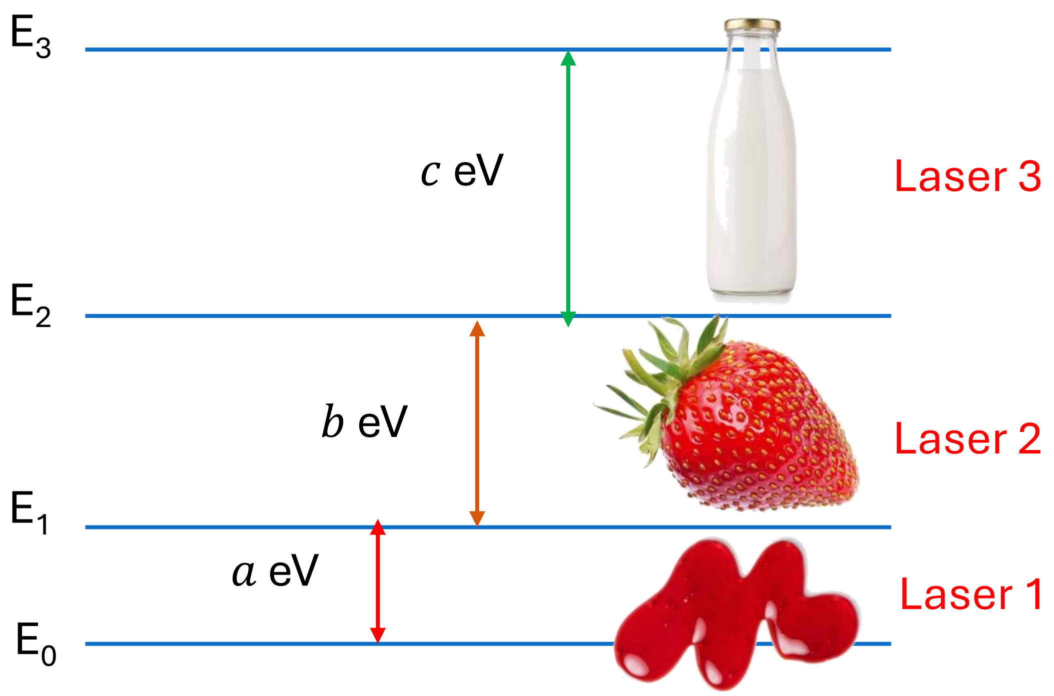
Isotope (2)



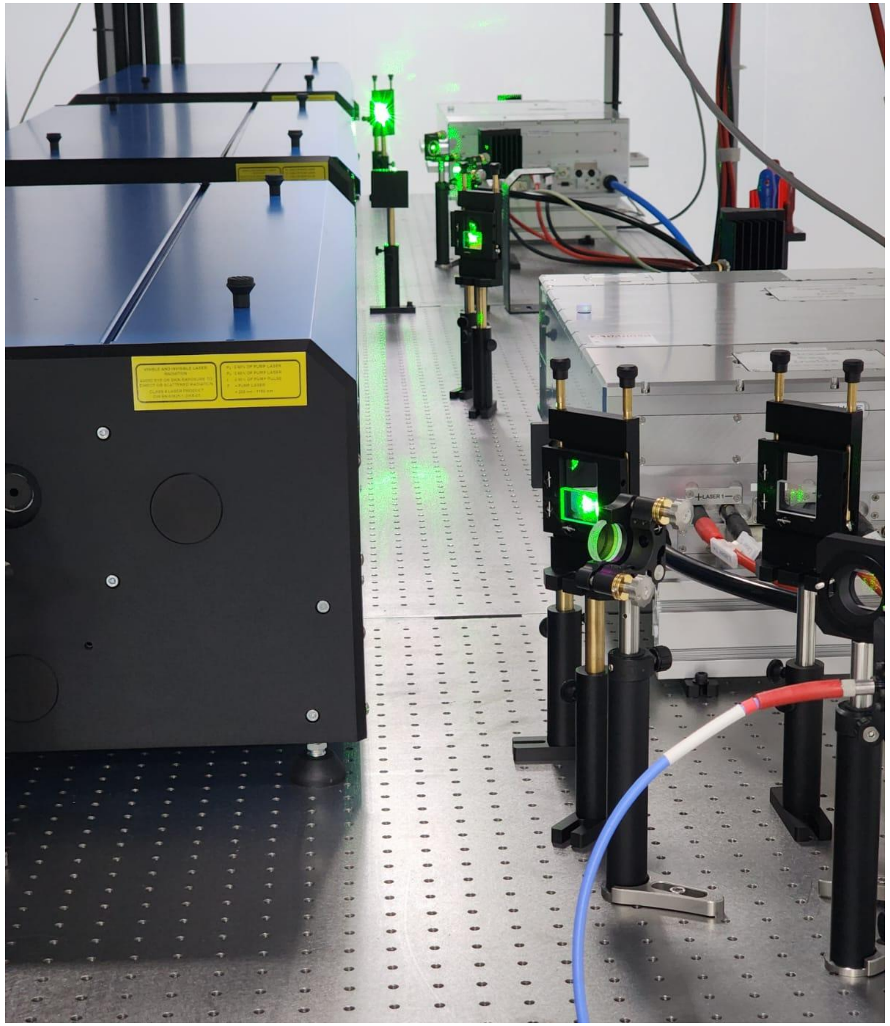
And <u>not</u> a chocolate milkshake

We need multiple lasers that are each “tuned” to make a certain ingredient

Isotope (1)

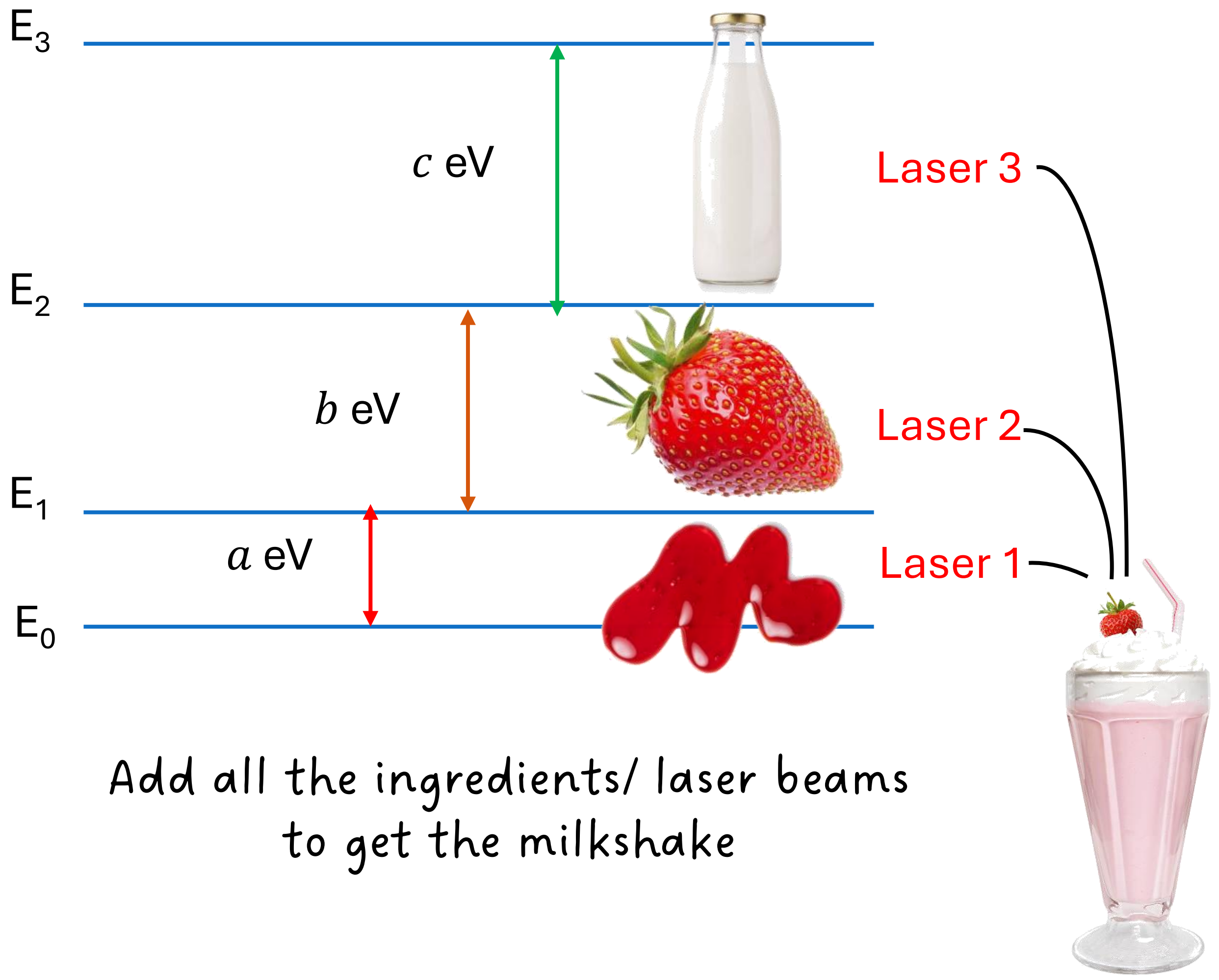


We use multiple lasers, each “tuned” to make a specific ingredient

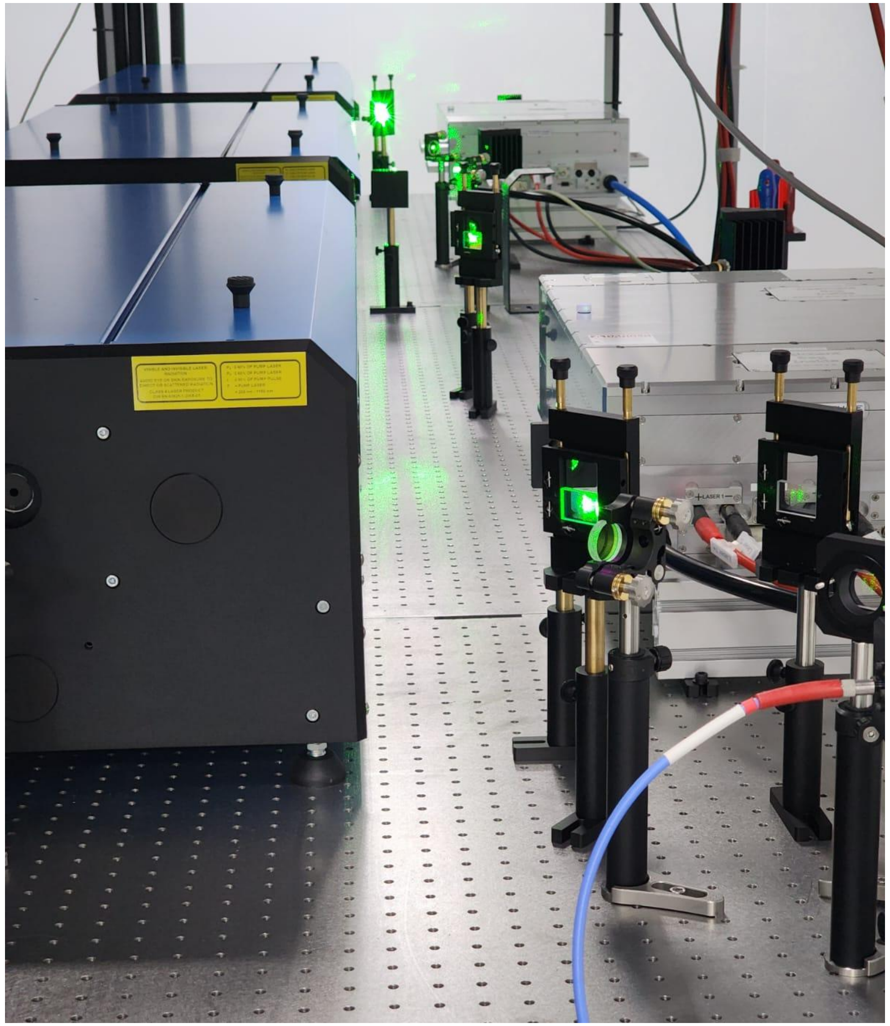


We need multiple lasers that are each “tuned” to make a certain ingredient

Isotope (1)

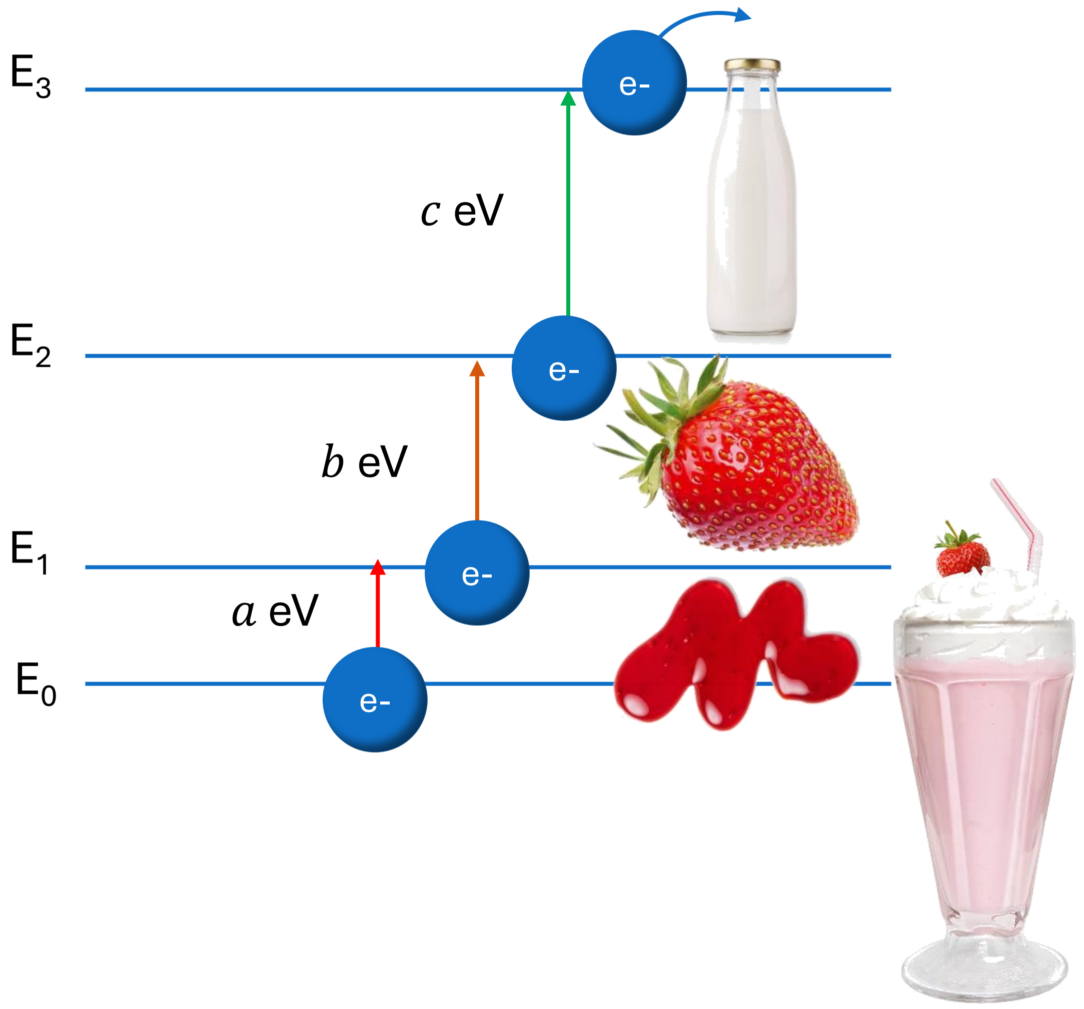


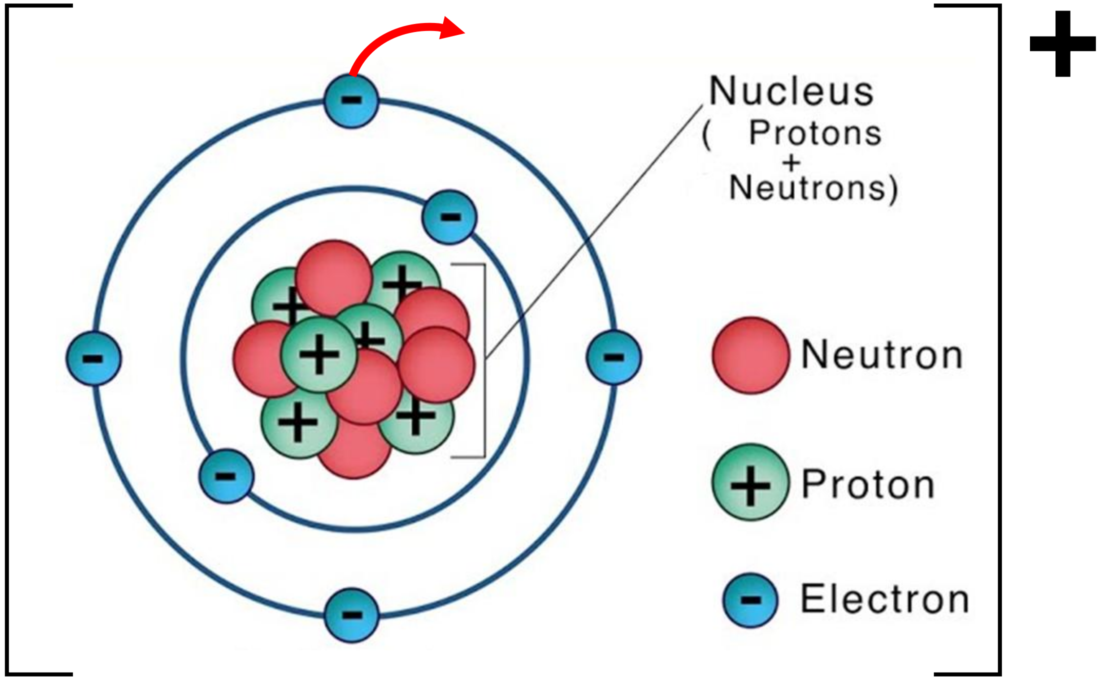
Add all the ingredients/ laser beams
to get the milkshake



Once you deliver the milkshake to the isotope, you selectively ionise it

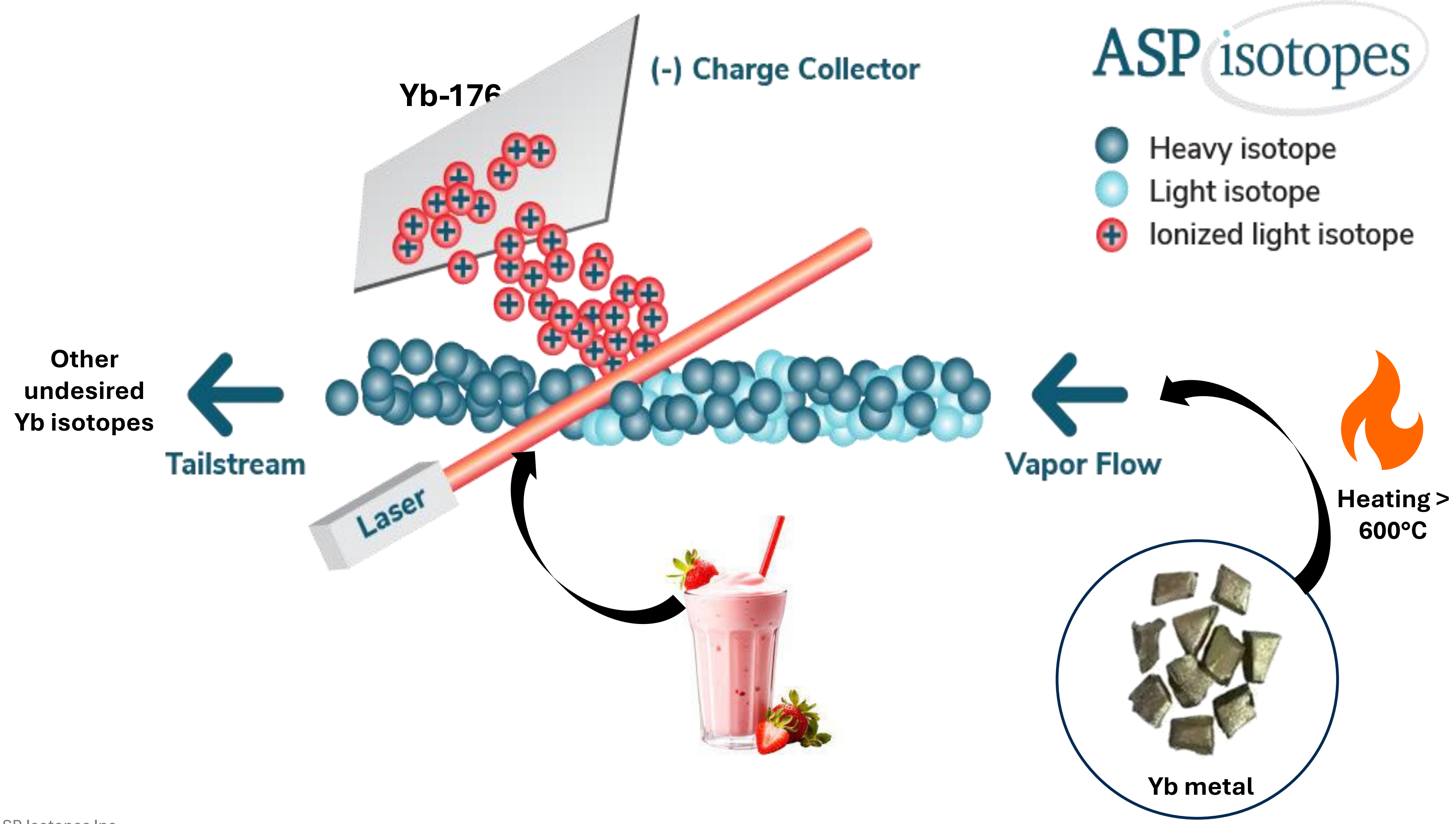
Isotope (1)



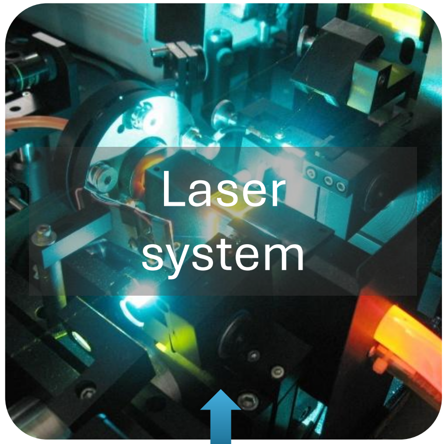


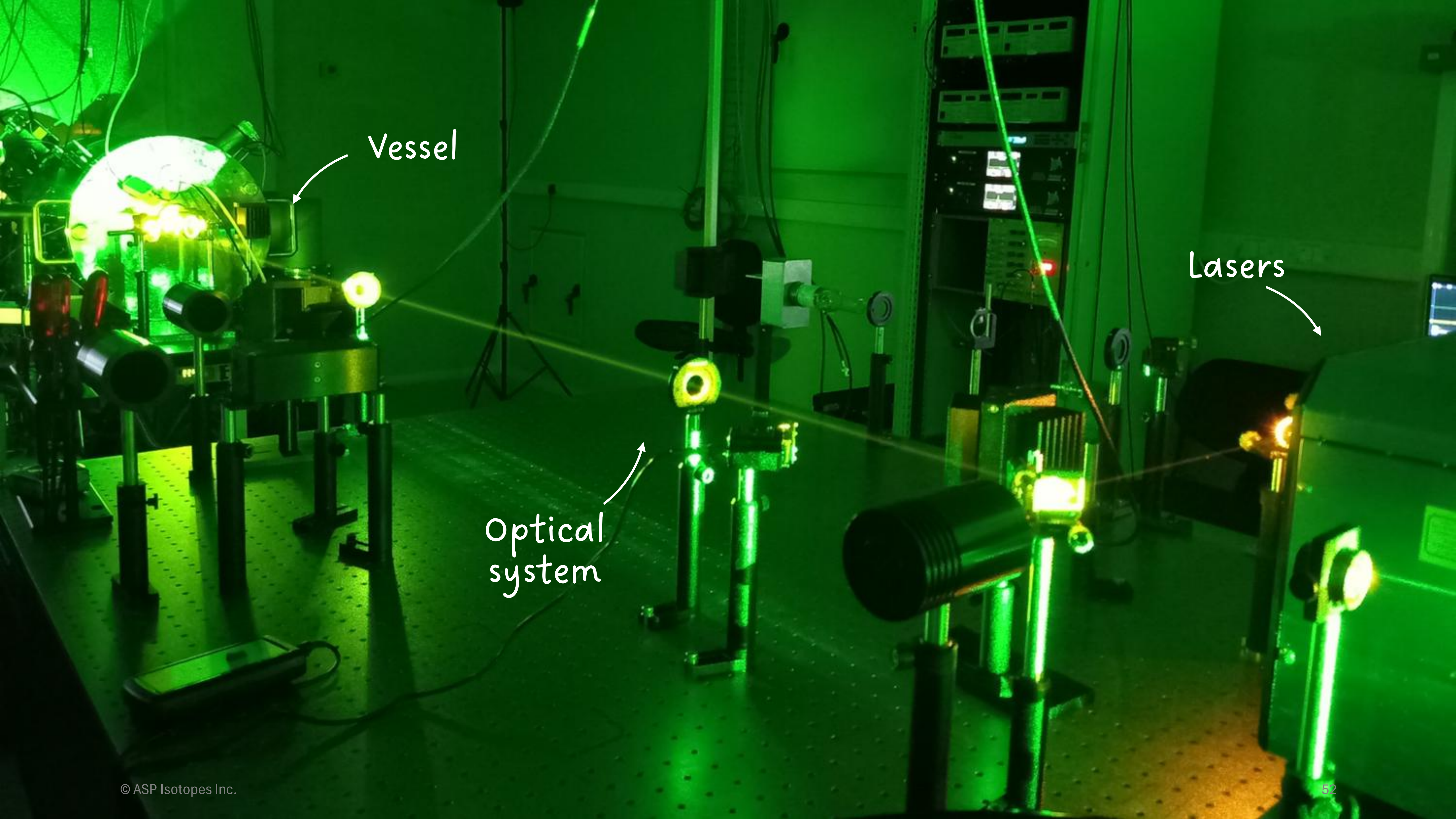
Successfully making & delivering a strawberry milkshake = ionising the desired isotope

Quantum enrichment = selective ionisation

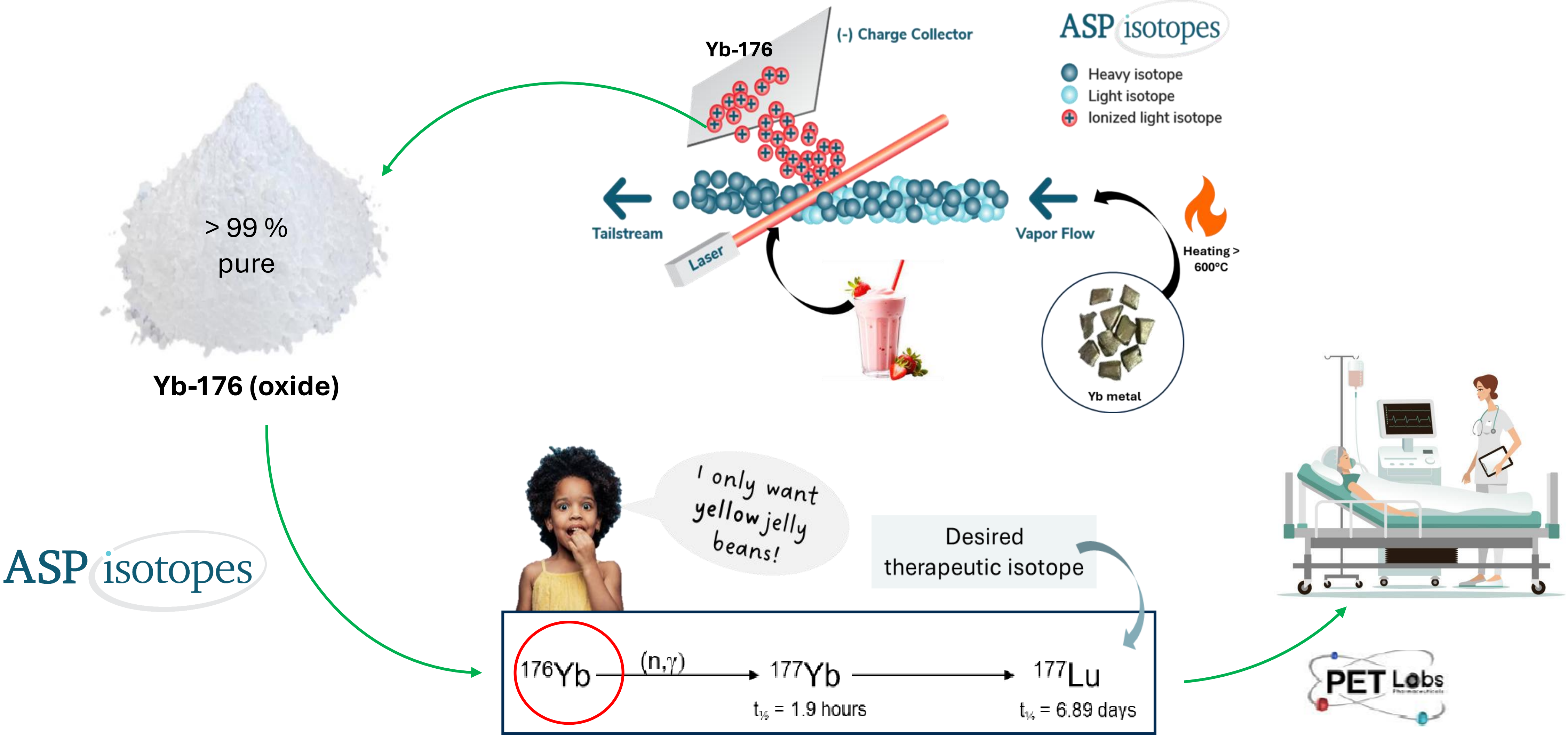


In the lab this is done using 3 critical systems




Vessel
Lasers
Optical
system

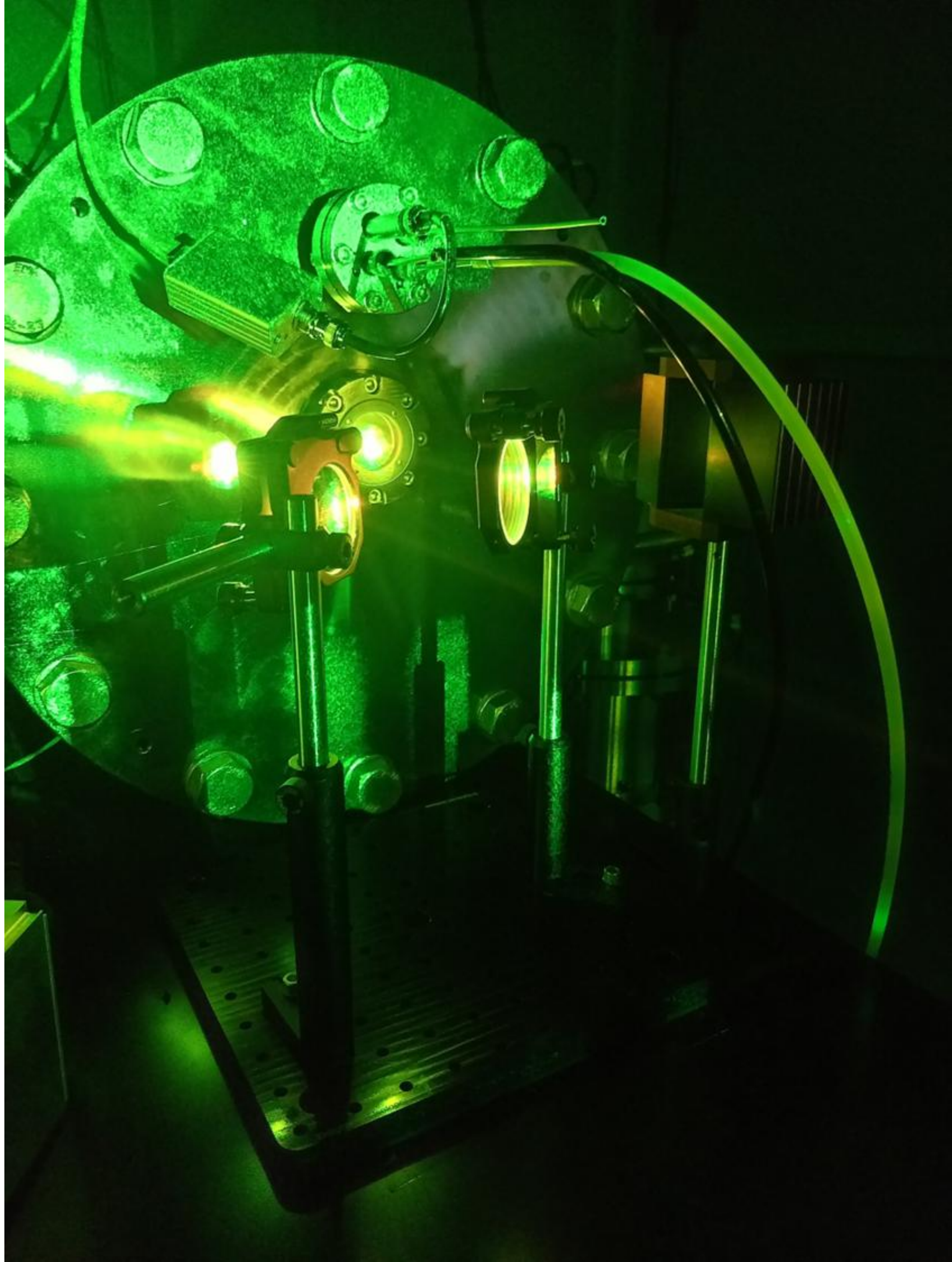
Through quantum enrichment we make lifesaving Yb-176



Summary

- Cancer (pancreatic) is a global crisis
- New drugs offer extraordinary breakthroughs (e.g., Lu177)
- Demand for highly pure (>99 %) isotopic samples (e.g., Yb-176) + g- kg quantities
- Traditional separation methods aren't suitable – high demand, low supply
- Exploit the quantum differences of isotopes to separate them
- Using lasers, quantum enrichment this is possible

Quantum enrichment enables the making of lifesaving isotopes



ASP isotopes

Thank you

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