

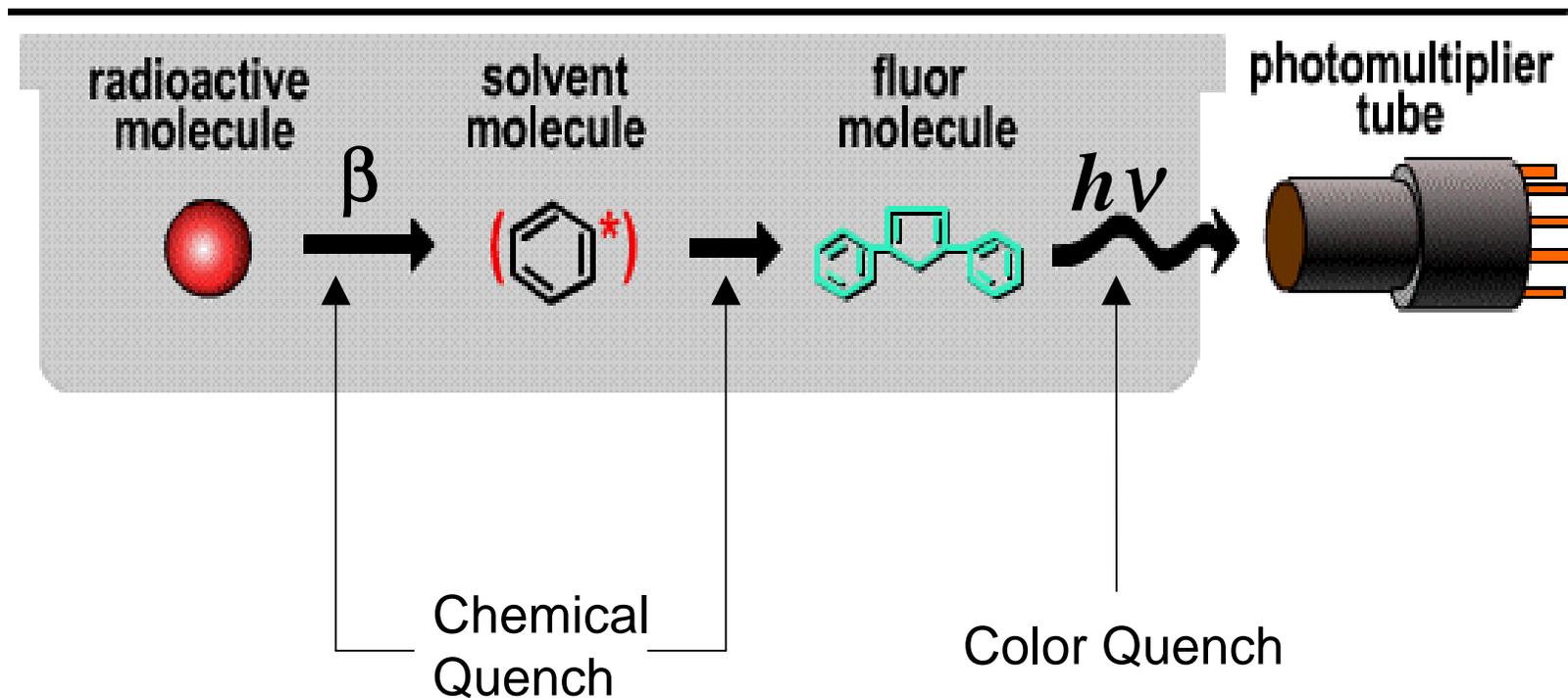
Quench & Quench Curves

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What is Quench?

- Basically, the liquid scintillation process is the conversion of the energy of a radioactive decay event into photons of light.
- Photomultiplier tubes (PMT's) are used to detect and convert the photons into electrical pulses. Both the sample and the scintillator are dissolved in an aromatic solvent, which allows energy to be transferred.
- **Any factor, which reduces the efficiency of the energy transfer or causes the absorption of photons (light), results in quenching in the sample.**

The Scintillation Process



Types of Quench

- There are two main types of quench:
 - **Chemical quench and Color quench.**
- **Chemical quench** occurs during the transfer of energy from the solvent to the scintillator. Any chemical species that is electronegative (electron capturing) will affect the energy transfer process by capturing or stealing the π electrons associated with the aromatic solvent and thus reduce the availability of π electrons necessary for efficient energy transfer.
- **Color quench** is an attenuation of the photons of light. The photons produced are absorbed or scattered by the color in the solution, resulting in reduced light output available for measurement by the PMT's

Quench

- The collective effect of quench is a reduction in the number of photons produced and therefore detected CPM (i.e. counts per minute).
- Counting efficiency is affected by the degree of quenching in the sample.
- Thus, to determine absolute sample activity (DPM), it is necessary to measure the level of quench of the samples first, then make the corrections for the measured reduction in counting efficiencies.

What is a Quench Curve?

- A quench standard curve is a series of standards in which the absolute radioactivity (DPM) per vial is constant and the amount of quench increases from vial to vial.
- A quench curve uses the relationship between counting efficiency and QIP to correct the measured CPM (counts per minute) to DPM (disintegrations per minute or absolute activity).

What is a Quench Curve?

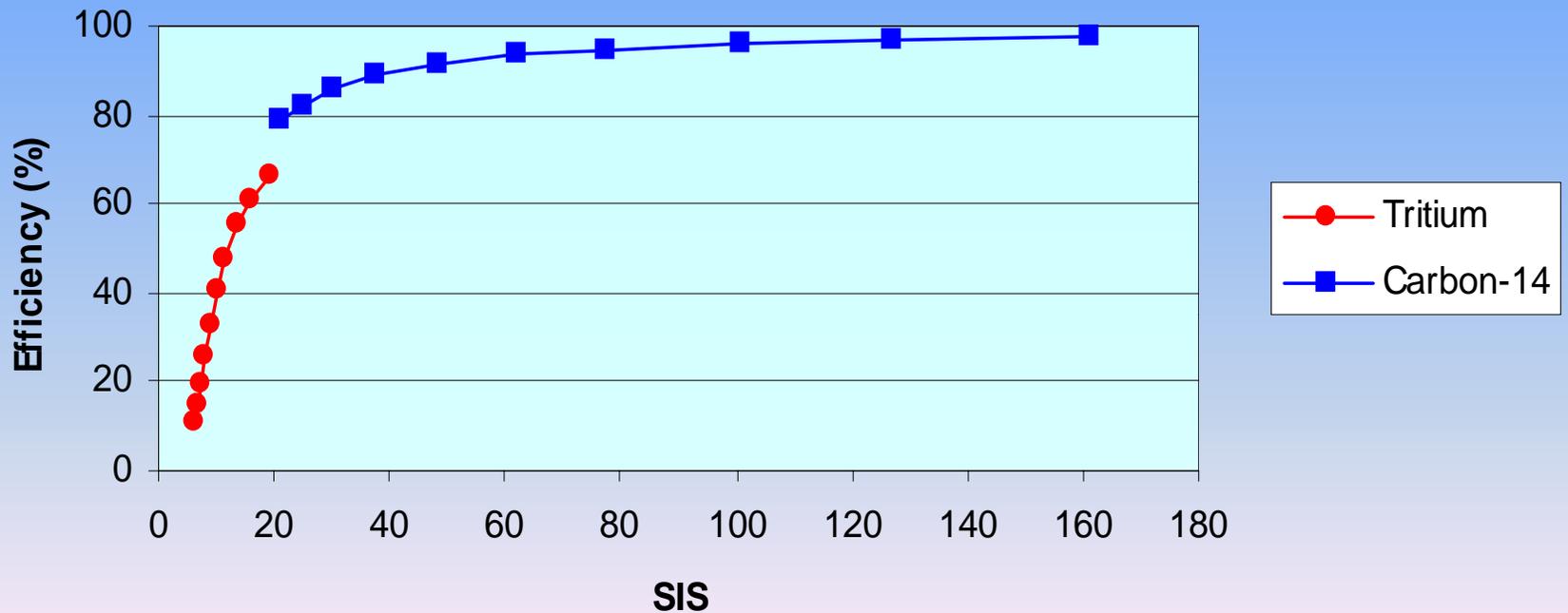
- When a quench curve is made, the DPM value in each standard is known. Each standard is counted and the CPM is measured. The counting efficiency is calculated using the following relationship:

$$\frac{\text{CPM} \times 100}{\text{DPM}} = \% \text{ Counting Efficiency}$$

- At the same time, the QIP is measured for each standard. A correlation is made using the QIP on one axis (X) and the % efficiency on the other axis (Y). A curve is fitted to the standard points.

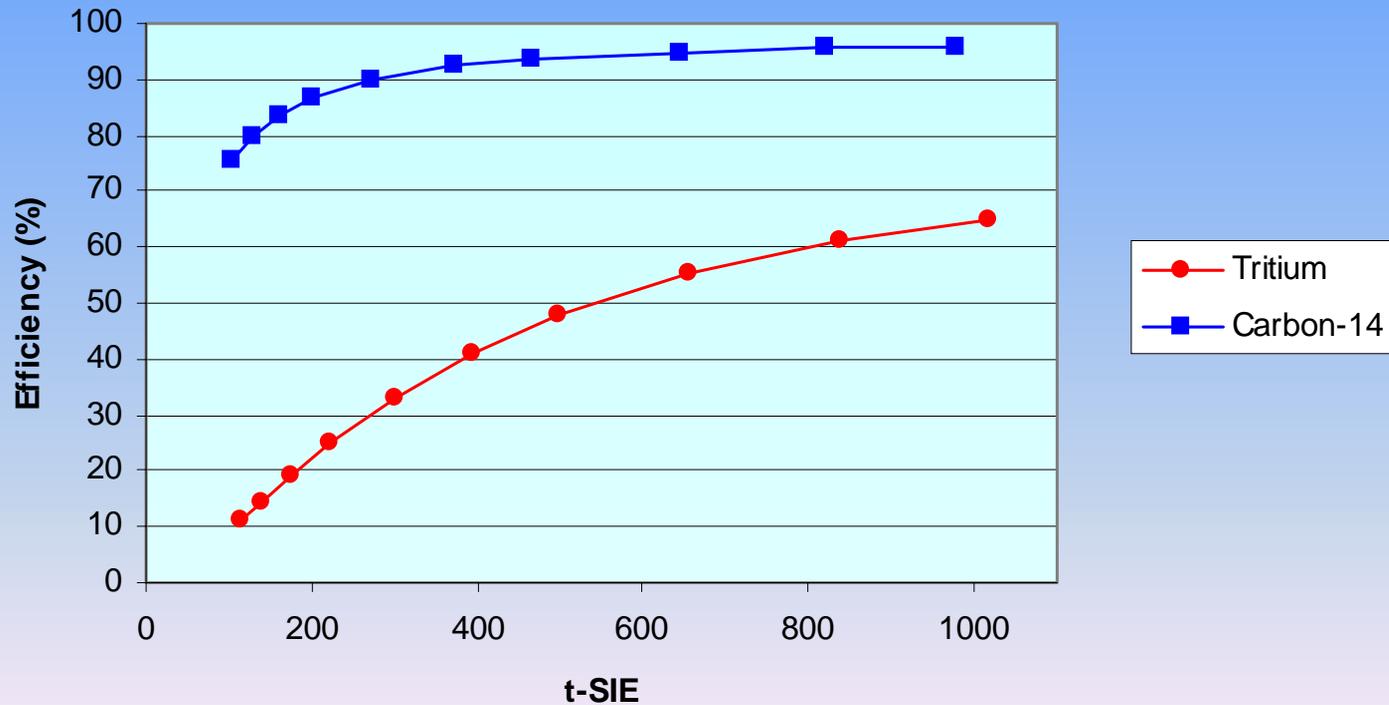
What is a Quench Curve?

Sample Spectrum SIS Quench Curve



What is a Quench Curve?

External Standard (t-SIE) Quench Curve



How is a Quench Curve used?

- ✓ Once the quench curve is stored in the instrument computer, it can be used for automatic DPM calculations.
- ✓ When unknowns are counted, the sample CPM and the QIP are measured.
- ✓ Using the QIP, the counting efficiency is determined from the quench curve.
- ✓ Sample DPM are calculated by applying the appropriate efficiency to the CPM of the sample :-

$$\text{DPM} = \frac{\text{CPM}}{\text{Efficiency (expressed as a decimal)}}$$

How is a Quench Curve used?

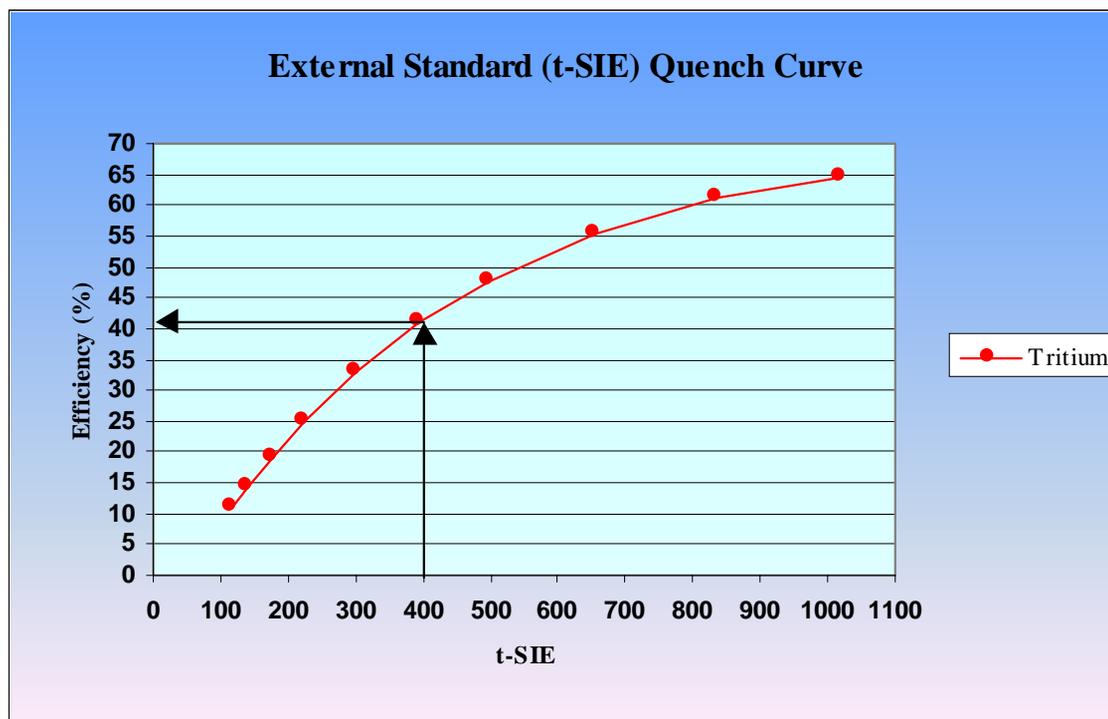
1. t-SIE is **400**
2. CPM = **10,000**
3. From Curve
Efficiency = 42%

4. Using $DPM = \frac{CPM}{\text{Efficiency}}$

Efficiency

$$DPM = \frac{10,000}{0.42} = 23,809$$

0.42



Using the Quench Curve

- ✓ t-SIE is independent of the sample isotope and of the activity in the vial, and has a large dynamic range. This makes it a very reproducible means of tracking the quench of the cocktail.
- ✓ SIS should only be used when there is **at least 500 CPM** activity in the sample. Remember that SIS uses the sample isotope spectrum to track quench; it is most accurate with high-count rate samples. For an accurate SIS a good sample spectrum needs to be acquired.
- ✓ SIS must not be used for low activity samples since an accurate sample spectrum cannot be acquired.

Using the Quench Curve

- ✓ Many customers prefer to purchase pre-prepared and certified quench standards.
- ✓ For cocktails using toluene, xylene, pseudocumene or LAB (Linear Alkyl Benzene) as the solvent, **Toluene Quench Standards should be used.**
- ✓ For cocktails using DIN (Di-isopropylnaphthalene) or PXE (Phenylxylylethane) as the solvent, **Ultima Gold Quench Standards should be used.**
- ✓ ***If the wrong quench standard is used there can be an error in DPM. This error is most pronounced with low energy isotopes such as Tritium.***

Tritium DPM Errors - Ultima Gold Quench Curve

	% error in Tritium DPM recovery				
	Ultima Gold (DIN)	Toluene	Opti-Fluor (LAB)	Insta-Gel Plus (pseudocumene)	Pico-Fluor 15 (pseudocumene)
No quench	- 0.12%	- 1.04%	+ 6.00%	+ 2.70%	+ 4.89%
Low quench	- 0.46%	+ 4.24%	+ 7.06%	+ 5.14%	+ 6.45%
Medium quench	+ 0.04%	+ 5.87%	+ 8.43%	+ 5.82%	+ 6.91%
High quench	- 0.14%	+ 10.10%	+ 14.41%	+ 10.02%	+ 11.89%
Highest quench	- 0.20%	+ 13.42%	+ 18.01%	+ 13.36%	+ 13.43%

Various Cocktails vs. Ultima Gold Quench Curve (Tritium)

Tritium DPM Errors - Toluene Quench Curve

	% error in Tritium DPM recovery				
	Ultima Gold (DIN)	Toluene	Opti-Fluor (LAB)	Insta-Gel Plus (pseudocumene)	Pico-Fluor 15 (pseudocumene)
No quench	- 4.10%	- 0.49%	- 0.57%	- 1.58%	- 0.32%
Low quench	- 5.33%	- 0.27%	- 0.13%	- 1.22%	+ 0.23%
Medium quench	- 6.51%	+ 0.01%	+ 0.45%	- 0.19%	+ 0.60%
High quench	- 10.39%	- 0.01%	+ 1.21%	- 0.79%	- 0.49%
Highest quench	- 16.16%	- 0.70%	+ 0.11%	+ 0.56%	- 0.21%

Various Cocktails vs. Toluene Quench Curve (Tritium)

Tritium DPM Errors

- These data show that the Ultima Gold Tritium quench curve should only be used with Ultima Gold cocktails for Tritium DPM measurements.
- Additionally they show that LAB based cocktails such as Opti-Fluor, Emulsifier Safe, and Formula- 989 **should not be used with the Ultima Gold quench curves for Tritium.**

Carbon-14 DPM Errors - Ultima Gold Quench Curve

	% error in Carbon-14 DPM recovery				
	Ultima Gold (DIN)	Toluene	Opti-Fluor (LAB)	Insta-Gel Plus (pseudocumene)	Pico-Fluor 15 (pseudocumene)
No quench	+ 0.06%	- 1.37%	+ 2.51%	+ 2.25%	+ 1.96%
Low quench	+ 0.03%	+0.12%	+ 2.04%	+ 0.78%	+ 0.80%
Medium quench	- 0.13%	+ 0.84%	+ 1.72%	+ 1.15%	+ 1.20%
High quench	+ 0.02%	+ 1.30%	+ 2.51%	+ 3.11%	+ 1.71%
Highest quench	- 0.63%	+ 4.52%	+ 3.81%	+ 3.59%	+ 2.77%

Various Cocktails vs. Ultima Gold Quench Curve (Carbon-14)

Carbon-14 DPM Errors - Toluene Quench Curve

	% error in Carbon-14 DPM recovery				
	Ultima Gold (DIN)	Toluene	Opti-Fluor (LAB)	Insta-Gel Plus (pseudocumene)	Pico-Fluor 15 (pseudocumene)
No quench	+ 0.45%	+ 0.42%	+ 1.71%	+ 1.90%	+ 1.96%
Low quench	+ 0.27%	- 0.03%	+ 0.89%	+ 1.20%	+ 0.43%
Medium quench	- 0.54%	- 0.37%	+ 1.28%	+ 0.31%	+ 0.83%
High quench	- 0.81%	+ 0.01%	+ 1.86%	+ 0.77%	+ 0.81%
Highest quench	- 6.51%	+ 0.33%	+ 1.04%	+ 0.49%	+ 0.88%

Various Cocktails vs. Toluene Quench Curve (Carbon-14)

Carbon-14 DPM Errors

With ^{14}C it can be seen that the two sets of quench curves can be intermixed except at high quench levels where the errors are increased.

Preparing a Quench Curve

How much Nitromethane should I add?

Quench Level	Toluene standards (15mL)	Ultima Gold standards (15mL)
A (1)	0 μ L	0 μ L
B (2)	1 μ L	5 μ L
C (3)	5 μ L	10 μ L
D (4)	11 μ L	15 μ L
E (5)	17 μ L	26 μ L
F (6)	25 μ L	45 μ L
G (7)	35 μ L	70 μ L
H (8)	45 μ L	110 μ L
I (9)	55 μ L	150 μ L
J (10)	66 μ L	230 μ L

Which Quench Curve to use?

Cocktail	Recommended Quench Curve (^3H AND ^{14}C)
Ultima Gold	Ultima Gold
Ultima Gold AB	Ultima Gold
Ultima Gold LLT	Ultima Gold
Ultima Gold MV	Ultima Gold
Ultima Gold XR	Ultima Gold
Ultima Gold F, Betaplate Scint	Ultima Gold
HiSafe2, HiSafe 3, TriSafe	Ultima Gold
Opti-Fluor / Opti-Fluor O	Toluene
Emulsifier-Safe / Formula-989	Toluene
Insta-Gel Plus, Aquasol, Aquasol-2, Aquassure	Toluene
Pico-Fluor 15 & 40, Biofluor, Atomlight	Toluene
Insta-Fluor Plus, Econofluor-2	Toluene
Hionic Fluor	Toluene
Filter-Count	Toluene
Carbosorb E / Permafluor E+	Toluene
Monophase S	Toluene

Quench Curves - Closing remarks

***Make sure you have the correct quench curve
for your LSC cocktail !!!***

When in doubt - prepare your own !!!