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# Prediction of Technetium-99m Yield from Molybdenum-99 Generators

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The prediction of the formation of a daughter product as the result of radioactive decay in a generator is complicated by the quantity of daughter product remaining in the generator after the last elution. Good laboratory practice indicates that there should be a method of predicting yield for comparison with on-site assay results.

The methods of computation are not difficult, but they can be much simplified for routine application. To describe the method it is necessary to begin with some basic concepts.

The decay scheme of $^{99}$Mo may be diagrammed as in Fig. 1. The percentages of the various branches are according to Crowther and Eldridge (1).

Because of the specific interest in the metastable state of Technetium-99, the pathway of interest is indicated in the above figure by the numerals I, II, and III.

The rates of disintegration for these three decay modes are given by (2):

1. $$dN_I = -\lambda_I N_I$$

2. $$\frac{dN_{II}}{dt} = \lambda_I N_I - \lambda_{II} N_{II}$$

3. $$\frac{dN_{III}}{dt} = \lambda_{II} N_{II}$$

Where N is the number of atoms present, $\lambda$ is the decay constant, and t is the elapsed time.

Using A to denote decay rate (Curiage), of the components, these equations may be expressed:

4. $$A_I = A^{\circ}_I \, exp(-\lambda_I t)$$

5. $$A_{II} = \frac{A^{\circ}_I}{\lambda_{II} - \lambda_I} [exp(-\lambda_I t) - exp(-\lambda_{II} t)] + A^{\circ}_{II} \, exp(-\lambda_{II} t)$$

A° denotes the activity of each nuclide present when t = 0. Because of the very long half-life, the amount of 99-Ru formed will be inconsequential and the equation for this transformation has been omitted. The last factor in Equation 5 expresses the residual $^{99m}$Tc in the generator after the last elution.

Only 87.6% of the $^{99}$Mo decays to $^{99m}$Tc and the equation must be corrected for this factor.

The conditions at transient equilibrium (t > 44 hours) is:

$$^{99m}\text{Tc activity} = 0.964\ ^{99}\text{Mo activity}$$

Figure two is a semilogarithmic plot of the decay of $^{99}$Mo and the formation of $^{99m}$Tc after total and incomplete elutions. It can be seen that the amount of $^{99m}$Tc available will be affected by the elution and should be considered in the calculation of the available quantity of technetium-99m.

In the practice of generator operation there are two conditions under which prediction may be desired: more than 44 hours since the last elution (transient equilibrium) and less than 44 hours since the last elution.

CASE I. More than 44 hours since the last elution.

In this case (transient equilibrium) the calculations are simple. Calculate the activity of the $^{99}$Mo at the time of elution by decay computation from the manufacturer's assay.

The total Technetium available will be 96.4% of the Molybdenum activity.

From the laboratory assay of the eluted $^{99m}$Tc, calculate the elution efficiency.

CASE II. Less than 44 hours since the last elution.

For this case a solution to Equation 6 is required. The electronic digital computer has been used to prepare a table of solutions.

Table I is a table of the decay of $^{99}$Mo and formation of $^{99m}$Tc following elution for various prior elution efficiencies from 40% to 90%. The table is used as follows:

From the elapsed time since the last elution and the $^{99}$Mo activity at that time, compute the current $^{99}$Mo activity. The entry in the table opposite the elapsed time in the column representing the last elution efficiency is the ratio

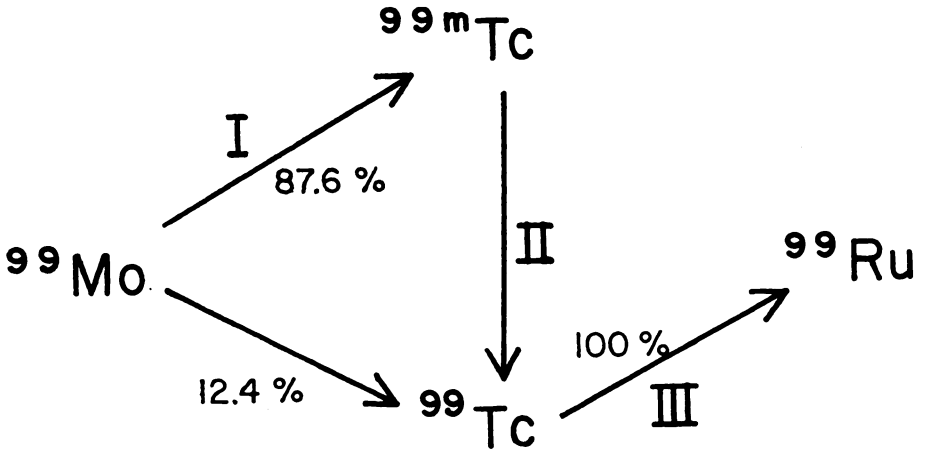


Fig. 1.

of $^{99m}Tc$ to $^{99}Mo$ activity. This factor multiplied by the $^{99}Mo$ activity yields the value of the total available technetium-99m.

SAMPLE PROBLEM.

At t = 0, $^{99}Mo$ = 100 mc.
$^{99m}Tc$ yield = 57.6 mc, or 60% elution efficiency.
At t = 24 hours, $^{99}Mo$ = (100) (0.780) = 78 mc.
$^{99m}Tc$ = (78) (0.91) = 71 mc.

TABLE I. 99m-Tc/99-Mo

| *Time since last elution* | *99-Mo (N/No)* | *0.40*[1] | *0.50*[1] | *0.60*[1] | *0.70*[1] | *0.80*[1] | *0.90*[1] |
|---|---|---|---|---|---|---|---|
| 0 | 1.000 | 0.53 | 0.44 | 0.35 | 0.26 | 0.18 | 0.09 |
| 4 | 0.960 | 0.68 | 0.62 | 0.56 | 0.50 | 0.44 | 0.38 |
| 8 | 0.921 | 0.77 | 0.73 | 0.70 | 0.66 | 0.62 | 0.58 |
| 12 | 0.883 | 0.84 | 0.81 | 0.70 | 0.76 | 0.73 | 0.71 |
| 16 | 0.847 | 0.88 | 0.86 | 0.85 | 0.83 | 0.81 | 0.80 |
| 20 | 0.813 | 0.91 | 0.90 | 0.89 | 0.87 | 0.86 | 0.85 |
| 24 | 0.780 | 0.93 | 0.92 | 0.91 | 0.91 | 0.90 | 0.89 |
| 28 | 0.748 | 0.94 | 0.94 | 0.93 | 0.93 | 0.92 | 0.92 |
| 32 | 0.717 | 0.95 | 0.95 | 0.94 | 0.94 | 0.94 | 0.93 |
| 36 | 0.688 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.94 |
| 40 | 0.660 | 0.96 | 0.96 | 0.95 | 0.95 | 0.95 | 0.95 |
| 44 | 0.633 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| 48 | 0.607 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |

[1]Elution Efficiencies

TABLE II. 99m-Tc RELATIVE YIELD

| *Time since last elution* | *99-Mo (N/No)* | *0.40*[1] | *0.50*[1] | *0.60*[1] | *0.70*[1] | *0.80*[1] | *0.90*[1] |
|---|---|---|---|---|---|---|---|
| 0 | 1.000 | 0.212 | 0.220 | 0.210 | 0.182 | 0.144 | 0.081 |
| 4 | 0.960 | 0.272 | 0.310 | 0.336 | 0.360 | 0.352 | 0.342 |
| 8 | 0.921 | 0.308 | 0.365 | 0.420 | 0.462 | 0.496 | 0.522 |
| 12 | 0.883 | 0.336 | 0.405 | 0.474 | 0.532 | 0.584 | 0.639 |
| 16 | 0.847 | 0.352 | 0.430 | 0.510 | 0.531 | 0.648 | 0.720 |
| 20 | 0.813 | 0.364 | 0.450 | 0.534 | 0.609 | 0.688 | 0.765 |
| 24 | 0.780 | 0.372 | 0.460 | 0.546 | 0.637 | 0.720 | 0.810 |
| 28 | 0.748 | 0.376 | 0.470 | 0.558 | 0.651 | 0.736 | 0.828 |
| 32 | 0.717 | 0.380 | 0.475 | 0.564 | 0.658 | 0.752 | 0.837 |
| 36 | 0.688 | 0.380 | 0.475 | 0.570 | 0.665 | 0.760 | 0.846 |
| 40 | 0.660 | 0.384 | 0.480 | 0.570 | 0.665 | 0.760 | 0.855 |
| 44 | 0.633 | 0.384 | 0.480 | 0.576 | 0.672 | 0.768 | 0.864 |
| 48 | 0.607 | 0.384 | 0.480 | 0.576 | 0.672 | 0.768 | 0.864 |

[1]Elution Efficiencies

If the elution efficiency is still 60%, the yield will be 60% of 71 mc, or 42.6 mc.

Table II is useful if the generator operation is sufficiently controlled to yield a relatively constant elution efficiency. This table is used in the same way as Table I, except that the last two computations are combined.

SAMPLE PROBLEM.

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$^{99m}$Tc yield = (78) (0.546) = 42.6 mc.

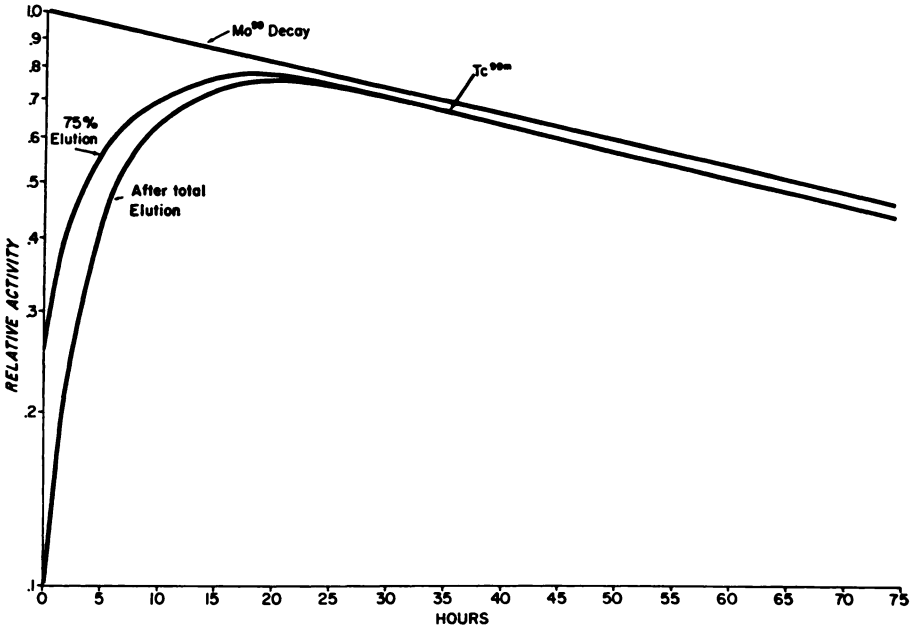


Fig. 2.


## SUMMARY

In the laboratory operation of the $^{99}$Mo/$^{99m}$Tc generators, it is customary to assay the eluant for specific activity and total activity of $^{99m}$Tc pertechnetate. A simple method is described which enables the user to compute the available $^{99m}$Tc at any time following elution.



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