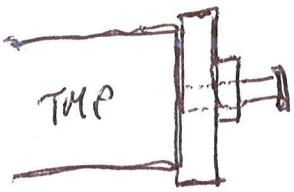
1a) He + Ar has the additional ionization mechanism of
(4) Penning ionization because the first excited state of He is higher in energy than that of Ar, thus $He^* + Ar \rightarrow He + Ar^+ + e^-$

b) Methane is a molecule and can "quench" the discharge by
(3) absorbing energy (particularly photons) without being ionized

c) The fill gas that contains any molecules will be damaged
(3) or degraded by the ionizing radiation and needs to be replaced to maintain uniform operation

2)

a)
(10)



ID of KF-25 is $\phi.935$ in (Lesker Catalogue) $\{25$ mm
length of hole $\approx \phi.78 + 1.79'' = 2.57'' \rightarrow 65.3$ mm
thus $L/R = 5.22 \rightarrow a = \phi.33$

$$\frac{1}{S_{eff}} = \frac{1}{S_{pump}} + \frac{1}{C_{PIPE}}$$

$C_{PIPE} = a\ 11.6 \frac{l}{s\text{-}cm^2} A$; $A = \pi(\phi.5\ cm)^2$

$C_p = \phi.33\,(11.6)\,\phi.785$ $\quad A = \phi.785\ cm^2$

$C_p = 3.\phi\phi\ L/s$

$$\frac{1}{S_{eff}} = \frac{1}{250\ \frac{L}{s}} + \frac{1}{3.\phi\phi}$$

$S_{eff} = 2.97\ L/s$ yikes!

b) Notice that the pipe is centered on the TMP – the center
(5) of a TMP has a connection to the drive shaft and a pumping speed of zero – the entering particles that land on the center support plate will most likely be emitted normal to the surface and back into the pipe!

3 a) The only difference is the phase of the solvent (i.e. liquid
(5) solution vs. solid solution of fluor). Some people mentioned this lowers radiation damage effects.

b) fluorescent light from singlet excited states to singlet ground state – fast
(5) phosphorescent light from triplet excited states to singlet ground state – slower that fluorescent light

3c) Bypass capacitors are used to maintain the voltages on the last dynodes of the PMT as the current from a pulse goes down the chain (and increases geometrically)

(5)

3d) In order for full energy absorption, ~~one~~ the last interaction has to be a photoelectric effect.

(5)

In order to get two interactions the first one has to be a Compton scattering event. (Pair production is ruled out by the energy.)

Thus ① Compton ② photoelectric

3e) True coincident summing is due to two photons from one reaction or decay entering a single gamma-ray detector. There are a few γ ray sources that emit one and only one γ ray per decay and thus ~~m~~ True coin. summing is not possible. Some people mentioned hold up in time due to meta stable states during decay.

(5)

4a) Sliding-scale linearization uses the "Gatti Register" to smooth out the DNL of an ADC when a large number of events are measured. The idea is to add a random offset to the signal, convert the data to digital word then subtract the digital random offset. They claim ADC is 16 bits 2^{16}, but output is $8K = 2^{13}$

(5)

thus the over sample is 3 bits $\Rightarrow 2^3 = 8$ channels

valid range will be $2^{13} - 2^3 = 8192 - 8 = 8184$ $\begin{cases} 1 \text{ to } 8194 \\ \text{or} \\ \emptyset \text{ to } 8193 \end{cases}$

no channel subtraction −1

4b) Successive approximation ADC has to step through all bits, one after another if there is one comparitor.

(5)

$t = t_{cycle} * 16 \text{ bits} = 10 \frac{ns}{bit} \times 16 = 160 ns$ $2^{13} \rightarrow -1$

4c) Wilkinson is a ramp system based on total number of channels (and not bits)

(5)

$t = \frac{1}{2} \text{ Full Scale} \times 2^{16} \frac{\text{channels}}{FS} \times 10 \frac{ns}{\text{channel}} = 5 \times 2^{16} ns$

$= 328. \mu s$

$2^{13} \rightarrow -1$

4d) FWHM at $\frac{1}{2}$ fullscale $= 2.354\left(\sigma_{DNL}^2 + \frac{\sigma_{INT}^2}{2}\right)^{1/2}$

(5)

$= 2.354\left((0.006)^2 + (0.0002)^2\right)^{1/2}$

only one contribution −2

$= 2.354(0.006) = 0.014$ or 1.4%

5a) $R_\gamma = 100\,\mu Ci\ {}^{137}Cs \times 3.7\times10^4 \frac{decay/s}{\mu Ci} * 0.851 \frac{\gamma}{decay} = 3.15\times10^6\ \gamma/s$

(5)

$\epsilon_{geo} \sim \frac{\pi(1.5\,in)^2}{4\pi\left(10\,ft * \frac{12\,in}{ft}\right)^2} = 3.91\times10^{-5}$

not 3" cylinder −1

$\epsilon_{INTRINSIC}$ from graph provided $\simeq 0.9$

no $\frac{\gamma}{decay}$ −1

R^γ Counts/s in detector $= R_\gamma * \epsilon_{geo} * \epsilon_{INT} = 3.15\times10^6 \frac{\gamma}{s} * 3.91\times10^{-5} \times 0.9$

$R_\gamma^\gamma = 110.8 \frac{\gamma}{s}$

5b) data is in one channel

(4)

sitting on background $\rightarrow R_{OBS} \simeq 495 - 350 = 145$ counts

$\Delta t_{Measure} \approx \frac{145\ counts}{111\ counts/s} = 1.3\ sec$

5b) Resolution for scintillator should scale with $1/\sqrt{E}$, 6.9% @ 662 from figure

(5)

Resolution @ 1332 keV $= 6.9\% \times \left(\sqrt{\frac{1332}{662}}\right)^{-1} = 6.9\% / 1.418 = 4.9\%$

no $\frac{1}{\sqrt{E}}$ −4

5d) ① before mean $\sim (351 + 349 + 354 + 345 + 350 + 355 + 352 + 342)/8$

~ 349.75

(6)

② after mean $\sim (295 + 310 + 340 + 290 + 305 + 340 + 340 + 299)/8$

~ 314.9

③ $\sigma \sim \sqrt{N}$, $\sqrt{349.75} = 19$ thus agree within 1σ.

$\sqrt{314.9} = 18$

5e) x-ray from Barium daughter of β^- decay at $\begin{cases}32.2\\31.8\end{cases}$ keV

(2)

5f) $R_\gamma = 4\,mCi\ ^{131}I * 3.7\times10^{7}\,\frac{d/s}{mCi} * 1\,\frac{\gamma}{decay} \times e^{-\frac{\ln 2 * 7d}{8.03d}}$

(8)

($T_{1/2} = 8.03$ days)

E_γ	
364.5 keV	81.5 %
637. keV	7.6 %
284. keV	6.1 %
80.	2.62 %
722	1.77 %
503	0.36 %
	99.95 %

$R_\gamma = 1.48\times10^{8}\, e^{-0.604}\ \gamma/s$

$R_\gamma = 8.09\times10^{7}\ \gamma/s$

$cts/s = 8.09\times10^{7}\,\frac{\gamma}{s} * 3.91\times10^{-5} * 0.9 = 2.85\times10^{3}\,\frac{cts}{s}$

Measurement $\approx 2.85\times10^{3}\,\frac{cts}{s} \times 1.3s = 3700.$ cts

(about 10x the observed BKG !!)

−1 for not total cts in time period