1a) He thr has the additional ionization mechanism of Penning ionization because the first excited state of He is higher in energy than that of Ar, thus He* + Ar → He + Ar+ + e-

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

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

2) a) FID of KF-25 is ϕ = 9.35 in. (Lesker Catalogue)

Length of hole ≈ ϕ/2 + 1.79'' = 2.57'' → 65.3 mm

thus L/P = 5.22 → a = 0.33

\[
\frac{1}{\text{P}} = \frac{1}{\text{Pump}} + \frac{1}{C_{\text{Pipe}}}
\]

\[
C_{\text{Pipe}} = a \frac{11.6 L}{\frac{\pi}{4} A^2} \quad \Rightarrow A = \frac{\pi}{4} (0.33 L)^2
\]

\[
C_{\text{Pipe}} = 0.33 (11.6) \phi 1.785 \quad \Rightarrow \phi = 3.97 L/a
\]

b) Notice that the pipe is centered on the TMP – the center 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.

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

b) Fluorescent light from singlet excited states to singlet ground state – fast

Phosphorescent light from triplet excited states to singlet ground state – slower than 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).

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

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 (Compton + 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 X-ray sources that emit one and only one X-ray per decay, and these are True Coin. Summing is useful. Some people mentioned holdup in time due to metastable states during decay.

4a) Sliding scale linearization uses the "Gate Register" to smooth out the DNH of an ADC where 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 $2^{13}$.

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

valid range will be $2^{13} - 2^3 = 8192 - 8 = 8184 \{ 1 \text{ to } 8194 \}$

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

$T = \frac{t_{cycle} \times 16 \text{ bits}}{16 \text{ bits per bit}} = 10 \text{ ms} \times 16 = 160 \text{ ms}$ $2^{13} = 160$

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

$T = \frac{1}{2} \cdot \frac{\text{Full Scale} \times 2^{16} \text{ channels}}{25} \cdot \frac{10 \text{ ms}}{\text{ channel}} = 5 \times 2^{16} \text{ ms}$

$2^{13} \rightarrow 1$

$2^{13} \rightarrow 32 \text{ ms}$
4d) \( \text{FWHM at } \frac{1}{2} \text{ fullscale} = 2.354 \left( \frac{\sigma_{\text{DL}}^2 + \sigma_{\text{IN}}^2}{2} \right)^{1/2} \)
\[= 2.354 \left( \frac{(\phi, \phi \Phi_6)^2 + (\Phi \Phi \Phi_2)^2}{2} \right)^{1/2} \]
\[= 2.354 (\phi, \phi \Phi_6) = 0.514 \pm 1.4\% \]

5a) \( R_0 = 1.00 \mu \text{Ci} \quad 137 \)C
\( C_s = 3.7 \times 10^4 \text{ decays/s} \times 0.85 \frac{\mu \text{Ci}}{\text{mCi}} \)
\( \text{decay} = 3.15 \times 10^6 \text{ s}^{-1} \)
\( \frac{C_s}{4 \pi (10 ft \times 12 in)^2} = 3.91 \times 10^{-5} \)
\( \text{with } 3 \text{ cylinder s}^{-1} \)
\( \text{no } \Phi \) decay
\( \text{intrinsic from graph provided } = \phi_9 \)

\( R_0 \) Counts/s in detector = \( R_0 \times \epsilon_{\text{geo}} \times \epsilon_{\text{IN}} = 3.15 \times 10^6 \times 3.91 \times 10^{-5} \times \phi_9 \)
\( R_0 = 114.8 \frac{\text{count}}{s} \)

5b) data is in one channel
\( \text{setting on background } \rightarrow R_{\text{obs}} = 495 - 35 \phi = 145 \text{ counts} \)

\( \text{At Measure } \approx \frac{145 \text{ counts}}{111 \text{ counts/s}} = 1.3 \text{ sec} \)

5c) Resolution for scintillator should scale with \( \frac{1}{\sqrt{E}} \), 6.9\% @ 662 keV
\( \text{from figure} \)
\( \text{Resolution @ 1332 keV} = 6.9\% \times \left( \frac{1332}{662} \right)^{-1} = 6.9\% \times 1.148 = 4.9\% \)

5d) ① before \( \text{mean } \sim \frac{(351 + 349 + 354 + 345 + 350 + 355 + 352 + 342)}{8} \)
\( \sim 349.75 \)

② after \( \text{mean } \sim \frac{(295 + 314 + 349 + 290 + 305 + 346 + 346 + 299)}{8} \)
\( \sim 314.9 \)

③ \( \sigma \sim \sqrt{n} \), \( \sqrt{349.75} = 19 \) thus agree within 1σ.
\( \sqrt{314.9} = 18 \)

5e) X-ray from Barium daughter \( \beta^- \) decay at 322.2 keV
\( E_{31.8} \)
5f) \[ R_y = 4 \text{ mCi} \times \frac{131}{1} + 3.7 \times 10^7 \text{ d/yr} \times \frac{1}{6} \times e^{-\frac{\ln 2 + 7d}{8.63}} \]

\[ (T_w = 8.03 \text{ days}) \]

\[ E_x = 364.5 \text{ keV} 81.5\% \]
\[ 637.0 \text{ keV} 7.6\% \]
\[ 284.1 \text{ keV} 6.1\% \]
\[ 80.0 \text{ keV} 2.62\% \]
\[ 722 \text{ eV} 1.77\% \]
\[ 503 \text{ eV} 0.36\% \]

\[ \frac{99.95\%}{\text{99.95\%}} \]

\[ cts/\Delta = 8.9 \times 10^3 \frac{c^2}{\Delta} + 3.91 \times 10^{-5} \times 0.9 = 2.85 \times 10^3 \frac{c^2}{\Delta} \]

Measurement \[ \times 2.85 \times 10^3 \frac{c^2}{\Delta} \times 1.3 = 3700 \text{ cts} \]

\[ \text{(about 1/3 \times the observed BK y)} \]

\[ \Delta t \text{ for nst total cts in time period} \]