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Chemical Physics Cume
Answer Key

Question 1

(a) A - recombination – positive and negative ions recombine and current collected is reduced (+1)

B - saturation – direct relation between radiation and produced ions in gas (+1)

C - proportional region – secondary ionization by electrons in electric field (+1)

D - limited proportionality - pulse heights are related, but not proportionally, to initial ionization intensity (+1)

E - Geiger region - pulse height independent of initial ionization (+1)

F - continuous discharge (+1)

(b) $\frac{M_1}{M_2} = 1 \qquad \frac{V_1}{\ln(b_1/a_1)} = \frac{V_2}{\ln(b_2/a_2)}$

$$\frac{4000}{\ln\left(\frac{2\text{cm}}{\frac{4\times10^{-2}\text{cm}}{2}}\right)} = \frac{x_2}{\ln\left(\frac{1\text{cm}}{\frac{4\times10^{-2}\text{cm}}{2}}\right)}$$

(+4)

$$\frac{4000}{6.90} = \frac{V_2}{6.21}$$

$V_2 = 3602\,V$

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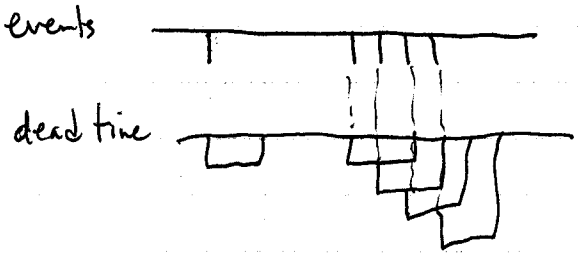
$P_1 a_1 = P_2 a_2$, since a_2 = constant

$P_1 = P_2 = 1$ bar methane (+3)

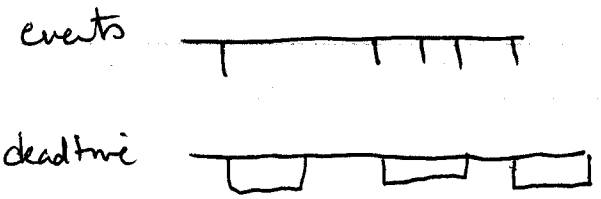
Question 2

Paralyzable (+4)



count 2 events

Non paralyzable (+4)



count 3 events

paralyzable – prolonged period during which no event is accepted

non paralyzable – events that come during dead period are ignored.

Measuring deadtime (+6)

① 2 source method. Count rates of two different sources are measured seperately and together.

② decaying source. Compare $T_{1/2}$ extracted to $T_{1/2}$ known.

for details, see Leo, "Techniqives for Nuclear and Particle Physics Experiments" (Springer, New York, 1994) p. 122

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Question 3

A – 1332 keV photo peak (+2)

B – 1173 keV photo peak (+2)

C – 1332 keV Compton edge (+2)

D – 1173 keV Compton edge (+2)

E – double escape peak 1332 keV (+2)

F – backscattering (+2)

Question 4

(+3) $R_A = (\varepsilon_{1A} + \varepsilon_{2A}) R_0$

(+3) $R_B = \varepsilon_{2B} R_0$ $\Rightarrow$ set "B" only to see radiation r_2 (+5)

(+3) $R_{AB} = \varepsilon_{1A} \varepsilon_{2B} R_0$

$$\therefore \quad \frac{R_A R_B}{R_{AB}} = \frac{(\varepsilon_{1A} + \varepsilon_{2A}) R_0 \, \varepsilon_{2B} R_0}{\varepsilon_{1A} \varepsilon_{2B} R_0}$$

$$= \left(\frac{\varepsilon_{1A} + \varepsilon_{2A}}{\varepsilon_{1A}} \right) R_0 = \boxed{\left(1 + \frac{\varepsilon_{2A}}{\varepsilon_{1A}} \right) R_0}$$

(+4)

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Question 5

(a) $\Delta E = \frac{v}{c} E_\gamma \cos\theta$ (+5)

$= \frac{1}{3}(908\,keV)\cos(42°)$

$= \boxed{225\,keV}$ (+5)

θ = angle between the directions of motion of the emitting nucleus and the emitted γ-ray

E_γ = γ ray energy

v = velocity of nucleus

c = velocity of light

$E_\gamma = E + \Delta E = 908\,keV + 225\,keV = \boxed{1133\,keV}$

(b) $\xrightarrow{15\,MeV}$ P $\xleftarrow{45\,MeV}$ ^{16}O

$(m_a + m_b)V_{cm} = m_a v_a + m_b v_b$

$(1+16)V_{cm} = 1\sqrt{\frac{15\,MeV}{2(1)}} + 16\sqrt{\frac{45\,MeV}{2(16)}}$

$17\,v_{cm} = 1\sqrt{\frac{15\cdot10^6 \cdot 1.602\times10^{-19}\,J/eV}{2\cdot1.660\times10^{-27}\,kg}} - 16\sqrt{\frac{45\cdot10^6\cdot1.602\times10^{-19}\,J/eV}{2\cdot16\cdot1.6602\times10^{-27}\,kg}}$

$= (1)2.12\times10^7\,m/s - 16(1.165\times10^7\,m/s)$

$= \frac{-1.65\times10^8\,m/s}{17}$

(+5) $v_{cm} = -9.717\times10^6\,m/s$

$T = \frac{1}{2}(m_p+m_p)v^2 = \frac{1}{2}\frac{(16)(1)}{(16+1)}\cdot1.66\times10^{-27}\,kg\left(-9.717\times10^6\,\frac{m}{s}\right)^2$

$= 1.25\times10^{-12}\,J \,/\, 1.602\times10^{-13}\,J/MeV$

$= 7.82\,MeV$ (+5) $\boxed{7.82\,MeV}$

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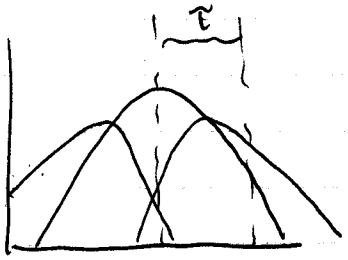
Question 6

The prompt curve will have (approximate) gaussian shape (+3)



One delay curve will have shape gaussian + exponential. The peak of the delayed curve will lie on prompt curve. (+3)

The first moment of the delay curves will be shifted by τ from centroid (first moment) of prompt curve (+3)

Overall variance (σ^2 delay) for the summed delay curve will be $\sigma^2_{prompt} + 2\tau^2$ (+3)

Mathematically (not required)

τ (lifetime) = $M_1[F(t)]_{(delayed)} - M_1[P(t)]_{(prompt)}$

$$M_2[F(t)] = M_2[P(t)] + 2M_1[P(t)]M_1[F(t)] + 2M_0[P(t)]M_1[F(t)]^2$$

if, for ref, $M_1[P(t)] = \phi$

$$M_2[F(t)] = M_2[P(t)] + \phi + 2M_1[F(t)]^2 = \boxed{M_2[P(t)] + 2\tau^2}$$

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Question 7

a) Gain $= \delta^n = 5^{12} = \boxed{2.44 \times 10^8}$ (+3)

b) % variance $= \left(\frac{\sqrt{\delta^n}}{\delta^n}\right)^2 \times 100 \ (\%) = \frac{1}{\delta}$

$= \frac{\sqrt{2.44\times10^8}}{2.44\times10^8} \times 100 = \boxed{6.4\times10^{-3}\%}$

for N stages

$= \frac{1}{\delta - 1}$

$= \frac{1}{5-1} = \frac{1}{4} = \boxed{25\%}$ (+3)

c) For one stage

$150\,eV = \frac{1}{2} m_e v^2$

$150\,eV \cdot 1.602\times10^{-19} \frac{J}{eV} = \frac{1}{2}(9.11\times10^{-31}\,kg)\, v^2$

$v^2 = 5.2755\times10^{13} \frac{m^2}{s^2}$

$= 7.26\times10^6\ m/s$

$t = \frac{d}{v} = \frac{12\,mm}{7.26\times10^6 m/s} = \frac{12\times10^{-3} m}{7.26\times10^6 m/s} = 1.65\times10^{-9} s$

$t_{ale} = 12 \cdot (1.65\times10^{-9} s) = 19.8\times10^{-9} s = \boxed{19.8\,ns}$ (+3)

d) $\frac{10^5}{s} \times 100 \times 2.44\times10^8 = 2.44\times10^{15} \frac{e^-}{sec} \times 1.602\times10^{-19} \frac{C}{e^-}$

$= 3.91\times10^{-4}\ C/s$

$= \boxed{391\,\mu Amp}$ (+3)