第二十六章：原子与原子核物理学（2003年－2017年）

选择题

① ${}^{30}_{15}P \longrightarrow {}^{30}_{14}Si + {}^{0}_{+1}e$

D

② ${}^{14}_{7}N + {}^{4}_{2}He \longrightarrow {}^{19}_{8}O + {}^{1}_{1}H$

D

③ A

④ $N(t) = N_0 e^{-\lambda t}$

$\frac{N(t)}{N_0} = e^{-\lambda t}$

$\frac{1}{4} = e^{-\lambda(60\times60)}$

$\lambda = 3.85\times10^{-4}\,s$ ✱

B

⑤ D

⑥ ${}^{4}_{2}He + {}^{14}_{7}N \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H$

C

⑦ D

⑧ B

⑨ ${}^{238}_{92}U \longrightarrow 3\,{}^{4}_{2}He + 2\,{}^{0}_{-1}e + {}^{226}_{88}X$

中子数 = 226 − 88

= 138

B

⑩ D

⑪

⑫ B

⑬ D

⑭ $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{18}{72} = \left(\frac{1}{2}\right)^{\frac{6}{T_{\frac{1}{2}}}}$

$T_{\frac{1}{2}} = 3$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$= \left(\frac{1}{2}\right)^{\frac{30}{3}}$

$= \frac{1}{1024}$ ✱

D

⑮ A

⑯ $F_B = F_B$

$qE = Bqv$

$E = Bv$

当 α 粒子的速率较小 $E > Bv$，电场力较强，α 粒子将向右偏转。

A

⑰ $2d\sin\theta = n\lambda$

$2\times2.81\times10^{-10}\sin\theta = 2\times3\times10^{-11}$

$\theta = 6.15°$ ✱

B

⑱ $2.82\times10^{-12}\times6.02\times10^{23} = 1.70\times10^{12}\,J$ ✱

B

⑲ A

⑳ $\frac{dN}{dt} = -\lambda N$

$\frac{dN_0}{dt} = -\lambda N_0$

$6400 = -0.0115\,N_0$

$N_0 = 5.565\times10^{5}$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{N}{5.565\times10^{5}} = \left(\frac{1}{2}\right)^{\frac{5\times60}{60.27}}$

$N = 1.77\times10^{4}$

B

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

$= \frac{\ln 2}{0.0115}$

$= 60.27\,s$

(21) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$ $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{N_A}{N_0} = \left(\frac{1}{2}\right)^{\frac{20}{4}}$ $\frac{N_B}{N_0} = \left(\frac{1}{2}\right)^{\frac{20}{5}}$

$N_A = \frac{N_0}{32}$ $N_B = \frac{N_0}{16}$

$N_A : N_B$

$\frac{N_0}{32} : \frac{N_0}{16}$

$1 : 2$

C

(22) $E = \frac{hc}{\lambda}$

$40 \times 1000 \times e = \frac{h \times 3 \times 10^8}{\lambda}$

$\lambda = 3.10 \times 10^{-11}\,m / 31.0\,pm$ #

C

(23) $\frac{mv^2}{r} = \frac{Kq_1q_2}{r^2}$

$mv^2 = \frac{ke^2}{r}$

$V = \frac{Ke^2}{mr}$

$T = \frac{2\pi r}{V}$

$= 2\pi r \sqrt{\frac{mr}{ke^2}}$

$= \frac{2\pi r}{e}\sqrt{\frac{mr}{k}}$ #

B

(24) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\ln\left(\frac{N}{N_0}\right) = \frac{t}{T_{\frac{1}{2}}} \ln\left(\frac{1}{2}\right)$

$\ln N - \ln N_0 = \frac{t}{T_{\frac{1}{2}}} \ln\left(\frac{1}{2}\right)$

$53 - 54 = \frac{60}{T_{\frac{1}{2}}} \ln\left(\frac{1}{2}\right)$

$T_{\frac{1}{2}} = 41.59\,min$ #

B

作答题

(1)(a)(i) $\frac{1}{2}mv^2 = qV$

$\frac{1}{2}m_e v^2 = e \times 30 \times 1000$

$v = 1.03 \times 10^8\,ms^{-1}$ #

(ii) $E = \frac{hc}{\lambda}$

$e \times 30 \times 1000 = \frac{h \times 3 \times 10^8}{\lambda}$

$\lambda = 4.136 \times 10^{-11}\,m$ #

(iii) $I = \frac{Q}{t}$

$I = \frac{ne}{t}$

$10 \times 10^{-3} = \frac{n}{t} \times e$

$\frac{n}{t} = 6.24 \times 10^{16}$ 个电子

∴只有10%的电子将其动能转变为X射线的能量，因此 6.24×10^{15} 个X光子产生

(b)(i) ${}^{9}_{4}Be + {}^{4}_{2}He \longrightarrow {}^{12}_{6}C + {}^{1}_{0}n$

(ii) 3kg铍的量：$\frac{3}{9 \times 10^{-3}} \times 6.02 \times 10^{23}$

$= 2.01 \times 10^{26}\,J$

3kg铍放出的能量 $= 2.01 \times 10^{26} \times 5.6\,Me$

$= 1.80 \times 10^{14}$

$\Delta E = \Delta m c^2$

$1.8 \times 10^{4} = \Delta m (3 \times 10^8)^2$

$\Delta m = 2g$ #

(c) $\frac{dN}{dt} = -\lambda N$

$\frac{dN}{dt} = -\frac{\ln 2}{T_{\frac{1}{2}}} \times N$

$3.7 \times 10^{10} = -\frac{\ln 2}{T_{\frac{1}{2}}} \times \frac{1}{226} \times 6.02 \times 10^{23}$

$T_{\frac{1}{2}} = 4.99 \times 10^{10}\,s^{-1}$

② (a)(i) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$= \left(\frac{1}{2}\right)^{\frac{4800}{1600}}$

$= \frac{1}{8}$ #

(ii) $^{226}_{88}Ra \longrightarrow {}^{206}_{82}Pb + 5\,{}^{4}_{2}He + 4\,{}^{0}_{-1}e$

5次α衰变和4次β衰变。

(b)(i) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$

(ii) $\Delta m = (235.0439 + 1.0087) - (140.913 + 91.8973 + 3 \times 1.0087)$

$= 0.2162\ u$ #

(iii) $\Delta E = 0.2162 \times 931\ MeV$

$= 201.28\ MeV$ #

③ (a)(i) $^{234}_{90}X_1 \longrightarrow {}^{234}_{92}X_2 + {}^{0}_{-1}e$

β射线

(ii) $^{234}_{92}X_2 \longrightarrow {}^{226}_{88}X_3 + 2\,{}^{4}_{2}He$

α射线

(b)(i)(ii)(iii) 看 Graph paper

④ (a) 放射性元素石碘131的样本含有160个原子，半衰期为8天，所以每经8天，样本将衰变一半，留下原来原子数的一半，即留下80个原子数。

(b) $N = N_0 e^{-\lambda t}$

$\frac{N}{N_0} = e^{-\lambda t}$

$\ln \frac{N}{N_0} = -\lambda t$

$\ln \frac{N_0}{N} = \lambda t$

$\ln \frac{N_0}{N} = \frac{\ln 2}{T_{\frac{1}{2}}} t$

故曲线斜率表示 $\frac{\ln 2}{T_{\frac{1}{2}}} = \lambda$，其代表的物理意义为衰变常数，即一粒原子每一单位时间的衰变机率。

(ii) $m = \frac{\ln 2}{T_{\frac{1}{2}}}$

$\frac{5-0}{2-0} = \frac{\ln 2}{T_{\frac{1}{2}}}$

$T_{\frac{1}{2}} = 0.277\ hrs$ #

(iii)① $N = N_0 e^{-\lambda t}$

$= 5\, e^{-\frac{5}{2} \times \frac{1}{3}}$

$= 2.17\ mg$ #

②

(c)(i) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$= \left(\frac{1}{2}\right)^{\frac{600}{300}}$

$= \frac{1}{4}$ #

(ii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$= \left(\frac{1}{2}\right)^{\frac{900}{300}}$

$= \frac{1}{8}$ #

(iii) $^{14}_{7}N + {}^{4}_{2}He \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H$

(iv) $^{7}_{3}Li + {}^{1}_{1}H \longrightarrow {}^{4}_{2}He + {}^{4}_{2}He$

⑤ (a)(i) $E = \Delta m c^2$

$= (-5.00810\times10^{-27} + 1.67492\times10^{-27} + 2\times3.34440\times10^{-27}) \times (3\times10^8)^2$

$= 5.202\times10^{-13}\ J$

$= 3.25\ MeV$ #

(ii) 核子数，总电荷，总质能和总线性动量。

(iii) 3 kg 的氚含有 9×10^{26} 的氚原子核；1 kg 的氚含有 3×10^{26} 的氚原子核。2个氚原子核释放 3.25 MeV；3×10^{26} 个氚原子/1 kg 的氚释放出 4.87×10^{26} MeV 的能量。

(b)(i) $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$ + 能量

α 粒子衰变

(ii) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$

核裂变

⑥ (i) $N = N_0 e^{-\lambda t}$

$\ln \frac{N}{N_0} = -\lambda t$

$\ln \frac{1}{2} = -\lambda T_{\frac{1}{2}}$

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

$= \frac{\ln 2}{0.0108}$

$= 64.18\ h$ #

(ii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^3$

$N = \frac{1}{8} N_0$ #

(iii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{240}{64.18}}$

$N = 0.075$ #

⑦ (a) • 使重核分裂成中等质量的核，以产生大量核能的核反应过程，称为核裂变。

• 使轻核结合成质量质大的核，以产生大量核能的核反应过程，称为核聚变。

(b) 原子核是核裂变反应，氢气弹则是核聚变反应。

(c) • 石墨、重水或普通水作减速剂，减慢中子的速度。

• 用镉，硼制成控制棒，吸收中子，控制链式反应速度。

(d)(i) $^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n + 17.6\ MeV$

(ii) $E = \Delta m c^2$

$17.6\ MeV = \Delta m \times (3\times10^8)^2$

$\Delta m = 3.13\times10^{-29}\ kg$ #

⑧ (a)(i) $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$

$= \frac{\ln 2}{12\times24\times3600}$

$= 6.69\times10^{-7}\ s^{-1}$ #

(ii) $A_0 = \lambda N_0$

$1.9\times10^7 = 6.69\times10^{-7} N_0$

$N_0 = 2.84\times10^{13}$ 核子 #

^{131}Ba 的初始质量 $= 2.84\times10^{13}\times2.175\times10^{-25}$

$= 6.18\times10^{-12}\ kg$ #

(iii) $\frac{A}{A_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{37000}{1.9\times10^{7}} = \left(\frac{1}{2}\right)^{\frac{t}{12}}$

$t = 108.05$ 天 #

(b) (i) $E = \Delta mc^2$

$= (235.0430u - 94.9058u - 138.906u - 1.0087u - 7\times0.0005u)\times(3\times10^{8})^2$

$= 3.27\times10^{-11}$ J #

(ii) 1 kg 的铀-235 释放的总能量

$\frac{1}{235.0430u}\times 3.27\times10^{-11} = 8.38\times10^{13}$ J #

⑨ (a) (i) 加热阴极，释放电子。

(ii) 将电子加速，增大电子的动能。

(iii) 将电子的动能转换成X射线。

(iv) 增加电子数量，增加X射线强度。

(v) $eV = \frac{hc}{\lambda}$

$1500e = \frac{h\times3\times10^{8}}{\lambda}$

$\lambda = 8.27\times10^{-10}$ m #

(b) (i) X射线的波长很短，与玻璃透射光栅的缝距相差多个数量级，不能产生衍射。

(ii) X射线在晶体中的原子平面上作镜面反射，反射光满足相干光条件，因而发生衍射现象。

(c) $2d\sin\theta = n\lambda$

$2\times2.82\times10^{-10}\times\sin 15°50' = \lambda$

$\lambda = 1.54\times10^{-10}$ m #

⑩ (a) (i) $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$

$= \frac{\ln 2}{25\times24\times3600}$

$= 3.21\times10^{-7}\ s^{-1}$ #

(ii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{N}{10^{23}} = \left(\frac{1}{2}\right)^{\frac{1}{25\times24\times3600}}$

$N = 9.9999968\times10^{22}$

衰变数目 $= 10^{23} - 9.9999968\times10^{22}$

$= 3.21\times10^{6}$ #

(iii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{10^{10}}{10^{23}} = \left(\frac{1}{2}\right)^{\frac{t}{25\times24\times3600}}$

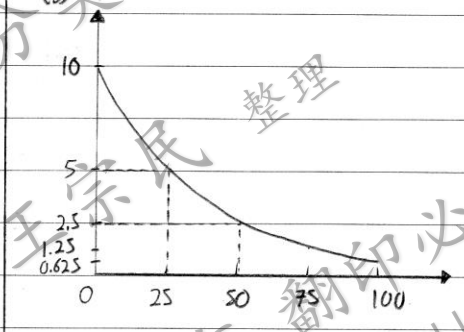
$t = 9.33\times10^{7}$ s / 1079.6 天 #

(iv) $A = \lambda N$

$= 3.21\times10^{-7}\times10^{10}$

$= 3210\ s^{-1}$ #

(b) N/$\times10^{23}$ 个



⑪ (a) ${}_1^1H + {}_1^1H \longrightarrow {}_1^2H + {}_1^0e + \nu$

${}_1^1H + {}_1^2H \longrightarrow {}_2^3He + \gamma$

${}_2^3He + {}_2^3He \longrightarrow 2\,{}_1^1H + {}_2^4He$

(b) 一系列的聚变可视为

$4\,{}_1^1H \longrightarrow {}_2^4He + 2\,{}_1^0e + 2\nu + 2\gamma$

$E = \Delta m c^2$

$= (4 \times 1.00813 - 4.00260 - 2 \times 0.00055)u \times (3 \times 10^8)^2$

$= 4.307 \times 10^{-12} J$ / $26.88 MeV$ #

(c) 质子数 $= \frac{2 \times 10^{30}}{1.67 \times 10^{-27}}$

$= 1.198 \times 10^{27}$ 个

(d) $E = Pt$

$1.198 \times 10^{27} \div 4 \times 4.307 \times 10^{-12} = 3.8 \times 10^{28} t$

$t = 3.39 \times 10^{16} s$ / 1.08×10^9 年 #

(12) (i) $E = \Delta m c^2$

$= (235.0439 - 147.9314 - 84.9156 - 2 \times 1.008\,7)u$

$(3 \times 10^8)^2$

$= 2.683 \times 10^{-11} J$ #

(ii) $E_T = Pt$

$n \times E = Pt$

$2.683 \times 10^{-11} n = 5 \times 10^6 \times 10 \times 3600$

$n = 6.71 \times 10^{21}$ 个 #

(13) (a) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}}$

$\frac{200}{201} = \left(\frac{1}{2}\right)^{\frac{t}{4.47 \times 10^9}}$

$t = 3.22 \times 10^7$ 年 #

(b) (i) ${}^4_2He + {}^9_4Be \longrightarrow {}^{12}_6C + {}^1_0n +$ 能量

(ii) $E = \Delta m c^2$

$\frac{1}{2} m v^2 = \Delta m c^2$

$\frac{1}{2} \times 1.008665u \times v^2 = (4.00260 + 9.01219 - 12 - 1.008665)u \times (3 \times 10^8)^2$

$v = 3.31 \times 10^7 ms^{-1}$ #

t	1	2	4	6	8	10	12
$\ln R$	8.04	7.80	7.30	6.81	6.30	5.80	5.30

$R = R_0 e^{-\lambda t}$

$\frac{R}{R_0} = e^{-\lambda t}$

$\ln R - \ln R_0 = -\lambda t$

$\ln R = -\lambda t + \ln R_0$

∴斜率表示衰变常数，λ.

$m = -\lambda$

$\frac{y_2 - y_1}{x_2 - x_1} = -\frac{\ln 2}{T_{\frac{1}{2}}}$

$\frac{7.7 - 5.5}{2.5 - 11.2} = -\frac{\ln 2}{T_{\frac{1}{2}}}$

$T_{\frac{1}{2}} = 2.74$ 小时 #

(2.5, 7.7)

(11.2, 5.5)