Classroom Activity Chapter 19 Number 1 10 April 2017

1. Complete and balance the following nuclear equations:

1a. ${}^{126}_{50}\text{Sn} \rightarrow {}^{0}_{-1}\text{e} +$ ${}^{126}_{51}\text{Sb}$

1b. ${}^{210}_{88}\text{Ra} \rightarrow {}^{4}_{2}\alpha +$ ${}^{206}_{86}\text{Rn}$

1c. ${}^{77}_{37}\text{Rb} \rightarrow {}^{0}_{1}\text{e} +$ ${}^{77}_{36}\text{Kr}$

1d. ${}^{76}_{36}\text{Kr} \rightarrow {}^{0}_{-1}\text{e} +$ ${}^{76}_{37}\text{Rb}$

1e. rhenium-160 → alpha particle + ${}^{156}_{73}\text{Ta}$
${}_{75}\text{Re}$ ${}^{4}_{2}\alpha$

1f. erbium-159 → positron + ${}^{159}_{67}\text{Ho}$
${}_{68}\text{Er}$ ${}^{0}_{1}\beta$

1g. beta emission of ${}^{157}_{63}\text{Eu} \rightarrow {}^{0}_{-1}\beta + {}^{157}_{64}\text{Gd}$

1h. electron capture of ${}^{126}_{56}\text{Ba} + {}^{0}_{-1}e \rightarrow {}^{126}_{55}\text{Cs}$

1i. alpha emission of ${}^{146}_{62}\text{Sm} \rightarrow {}^{4}_{2}\alpha + {}^{142}_{60}\text{Nd}$

jg. positron emission of ${}^{125}_{56}\text{Ba} \rightarrow {}^{0}_{1}\beta + {}^{125}_{55}\text{Cs}$

2. Complete and balance the following nuclear equations:

2a. ${}^{24}_{11}\text{Na} \rightarrow {}^{24}_{12}\text{Mg} +$ ${}^{0}_{-1}\beta$

2b. ${}^{218}_{85}\text{At} \rightarrow {}^{214}_{83}\text{Bi} +$ ${}^{4}_{2}\alpha$

2c. ${}^{135}_{60}\text{Nd} \rightarrow {}^{135}_{59}\text{Pr} +$ ${}^{0}_{+1}\beta$

2d. uranium-239 → neptunium-239 + ${}^{0}_{-1}\beta$
92 93

3. ${}^{226}\text{Ac}$ can decay by three different nuclear processes, α-emission, β-emission, and electron capture. Write a balanced equation for each of these processes for ${}^{226}\text{Ac}$.

$${}^{226}_{89}\text{Ac} \rightarrow {}^{4}_{2}\alpha + {}^{222}_{87}\text{Fr}$$

$${}^{226}_{89}\text{Ac} \rightarrow {}^{0}_{-1}\beta + {}^{226}_{90}\text{Th}$$

$${}^{226}_{89}\text{Ac} + {}^{0}_{-1}e \rightarrow {}^{226}_{88}\text{Ra}$$

4. Of the two isotopes of iodine, ${}^{136}\text{I}$ and ${}^{122}\text{I}$, one decays by beta emission and one by positron emission. Which does which?

${}^{136}\text{I}$ has too many electrons and decays by β-decay

${}^{122}\text{I}$ positron

5. Radon-222 decays by a series of three α-emissions and two β-emissions. What is the final stable nucleus?

$${}^{222}_{86}\text{Rn} \rightarrow 3\,{}^{4}_{2}\alpha + 2\,{}^{0}_{-1}\beta + {}^{210}_{82}\text{Pb}$$

Questions in final exam format:

6. Which of the following statements about positrons is **false**?
   - T A. The positron has same mass as an electron. T
   - T B. A positron is ejected from the nucleus during the conversion of a proton into a neutron. ${}^{1}_{1}p \rightarrow {}^{0}_{1}\beta + {}^{1}_{0}n$
   - T C. A positron is a positive electron.
   - F [✓ D.] When positron emission occurs, the atomic number of the nucleus increases.

7. Which of the following statements about electron capture is **false**?
   - A. The electron is used to convert a proton to a neutron.
   - [✓ B.] The electron involved is most likely an outer shell valence electron.
   - C. In electron capture decay, the atomic number decreases by one.
   - D. In electron capture decay, the mass number remains unchanged.

8. Which process **decreases** the neutron/proton ratio?
   - A. alpha emission
   - [✓ B.] beta emission
   - C. electron capture
   - D. positron emission

Classroom Activity Chapter 19 Number 2 12 April 2017

1. The half-life of plutonium-239 is 24,000 years.

1a. What is the decay constant (rate constant)?

$$k = \frac{.693}{24000} = 2,9 \times 10^{-5}\ yr^{-1}$$

1b. What fraction of a sample of Pu-239 remains after 1000 years?

$$\ln\left(\frac{N_0}{N_t}\right) = 2,9 \times 10^{-5}\ yr^{-1} * 1000\ yr$$

$$\frac{N_0}{N_t} = 1,029 \qquad \boxed{\frac{N_t}{N_0} = 0,97}$$

2. What fraction of a sample of a radioactive isotope remains after 3 half lives? After 10 half lives?

$$\frac{1}{2^3} = 0,125 \qquad \frac{1}{2^{10}} = 9,8 \times 10^{-4}$$

3. The age of igneous rock that has solidified from magma can be analyzed by the amount of ^{40}K and ^{40}Ar it contains. No ^{40}Ar would be present in the initial rock as it is a gas; all of it is created by the following decomposition: $^{40}K \rightarrow {}^{40}Ar + {}^{0}_{+1}\beta$ $t_{1/2} = 1.25 \times 10^9$ yrs. What is the minimum age of the rock if it contains 3.35 mg ^{40}K and 0.25 mg ^{40}Ar?

$$k = .693/1,25 \times 10^9\ yr = 5,5 \times 10^{-10}$$

$$\ln\left(\frac{3,35 + 0,25}{3,35}\right) = 5,5 \times 10^{-10} \cdot t$$

$$t = 1,3 \times 10^8\ yr$$

Its ok to use masses bcz both are mass 40

4a. A sample of radioactive ^{28}Mg decays at a rate of 53,500 disintegrations/min (dpm), but after 48 hrs, the decay rate drops to 10,980 dpm. What is the half-life of this isotope?

$$\ln\left(\frac{53500}{10980}\right) = k\ 48$$

$$k = 3,3 \times 10^{-2}$$

$$t_{1/2} = \frac{.693}{k} = 21,0\ hr$$

4b. Can you predict if ^{28}Mg is a β-emitter? Explain.

Magnesium has atomic mass of 24,3 g/mol, Therefore Mg-28 has too many neutrons: β-emitter

5. All living organisms contain an amount of C-14 that gives 15.3 dpm per gram of carbon. Given that the half-life for C-14 is 5720 yrs, what is the rate of decay in dpm/g C for a mummified turtle that is thought to be 4000 years old?

$$\ln\left(\frac{15,3}{N_t}\right) = 1,21 \times 10^{-4}\ yr * 4000\ yr$$

$$k = \frac{.693}{5720} = 1,21 \times 10^{-4}\ yr$$

$$\ln\left(\frac{15,3}{N_t}\right) = 0,485$$

$$\frac{15,3}{N_t} = 1,62$$

$$N_t = 9,42\ dpm/g\ C$$

6. Using the information above, how old is an artifact that emits 6.0 dpm/g C?

$$\ln\left(\frac{15,3}{6,0}\right) = 1,21 \times 10^{-4}\ yr * t$$

$$t = 7730\ yr$$

7. Iodine-123, used in thyroid therapy, has a half-life of 13.27 hours. How many half-lives are required for a 160 mg sample of iodine-123 to decay to 5.0 mg?

A. 0.031

B. 1.0

[✓ C. 5.0]

D. 32

$$\frac{160}{5} = 2^x = 32$$

$$x = 5$$

Classroom Activity Chapter 19 Number 3 12 April 2017

1. ^{36}Cl is a β-emitter with a half life of 3.0 x 10^5 years. How many β-emissions are emitted in one minute from a 5.0 mg sample of chlorine-36?

$k = \frac{.693}{3.0 \times 10^5} = 2,31 \times 10^{-6}\ yr^{-1}$

$rate = \frac{2,31 \times 10^{-6}}{yr} \left| \frac{1\ yr}{365d} \right| \frac{d}{24h} \left| \frac{h}{60 min} \right.$

$= 4,4 \times 10^{-12}\ min^{-1} * N_{Cl}$ atoms

5,0mg Cl → → $8,36 \times 10^{19}$ Cl atoms

$rate = 4.4 \times 10^{-12}\ min^{-1} * 8.36 \times 10^{19}$ atoms

$= 3,7 \times 10^{8}$ dpm

⇒ $3,7 \times 10^{8}$ β-particles/min

2a. Calculate the mass defect in g/mol for S-32 (atomic mass 31.97207 u). Given: the mass of one neutron is 1.00866 amu and the mass of one proton is 1.00728 amu.

Isotopic mass with 16 electrons

16 p 16 × 1,00728 =

16 n 16 × 1,00866 = $\underline{32.25504}$

↑ Σ nucleons

16e: $16 * 5,486 \times 10^{-4}$

Actual (nucleus only)

$$\begin{array}{r} 31,97207 \\ -\ \underline{0,0087776} \\ 31.96329 \end{array}$$

→ Δm = 0,2917 g/mol

2b. Calculate the binding energy in MeV/nucleon for S-32.

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

$= 0,2916 \times 10^{-3}\ kg * (3.0 \times 10^8 \frac{m}{s})^2$

$= 2,63 \times 10^{13} \frac{J}{mol} = 2,63 \times 10^{10} \frac{kJ}{mol}$

$1\ MeV = 1,602 \times 10^{-13}\ J$

And divide by $N_A * 32$:

E = 8,51 MeV/nucleon

3. Mg-28 (isotopic mass 27.98388 u) is a β-emitter that decays to Al-28 (isotopic mass 27.98191 u). How much energy is associated with this reaction in units of kJ/mol?

${}^{28}_{12}Mg \rightarrow {}^{0}_{-1}\beta + {}^{28}_{13}Al$

27,98388 ↑ $\underbrace{27,98191 \quad 5,486 \times 10^{-4}}_{27.98246}$

$\Delta m = 1,42 \times 10^{-3} = 1,42 \times 10^{-6}$ kg

$\Delta E = 1,28 \times 10^{11}$ J

$= 1,28 \times 10^{8}$ kJ/mol

4. Balance the following nuclear transformations.

A. ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr +$ ___ ${}^{1}_{0}n$

B. ${}^{239}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{146}_{56}Ba + \underline{{}^{90}_{38}Sr} + 3\,{}^{1}_{0}n$

C. ${}^{246}_{96}Cm + {}^{12}_{6}C \rightarrow \underline{{}^{254}_{102}No} + 4\,{}^{1}_{0}n$

D. ${}^{247}_{100}Fm \rightarrow \underline{{}^{4}_{2}\alpha} + {}^{243}_{98}Cf$

E. ${}^{253}_{99}Es + \underline{{}^{4}_{2}\alpha} \rightarrow {}^{256}_{101}Md + {}^{1}_{0}n$

F. ${}^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2\,{}^{1}_{1}H$

G. ${}^{250}_{98}Cf + {}^{11}_{5}B \rightarrow \underline{{}^{257}_{103}Lr} + 4\,{}^{1}_{0}n$

5. Which of the above are examples of…

5a. a fission reaction? A B

5b. a fusion reaction? F

5c. a decay process? D

5d. a nuclear transmutation? C E G

6. Nitrogen-14 (14.003074 amu) is synthesized in the sun by fusion of ^{13}C (13.003355 amu) and ^{1}H (1.007825 amu). How much energy is released in this nuclear reaction?

A. 2.432 × 10^6 kJ/mol
[✓ B.] 7.295 × 10^8 kJ/mol
C. 9.141 × 10^{10} kJ/mol
D. 1.807 × 10^{11} kJ/mol

$$\begin{array}{r} 13,003355 \\ +\ 1,007825 \\ -\ \underline{14.003074} \end{array}$$

$\Delta m = 8,11 \times 10^{-3}$ g

$= 8,1 \times 10^{-6}$ kg

$E = 7,3 \times 10^{11}$ J

$= 7,3 \times 10^{8}$ kJ