Binding energy

1. YF.43.9 A photon with wavelength $3.5\ 10^{-13}\ m$ strikes a deuteron ($E_{b/n} = 1.112\ MeV$) splitting it into a proton and a neutron.

a) Calculate the kinetic energy released in this interaction;

b) Assuming the two particles share the energy equally, and taking their masses to be $1\ u$, calculate their speeds after the photo-disintegration.

Answer: $1.32\ MeV$; $1.1\ 10^{7} m/s$

Radioactive decay law

2. HR.p1176. The table shows some measurements of the decay rate of a sample of ${}^{128}_{53}I$, a radionuclide often used medically as a tracer to measure the rate at which iodine is absorbed by the thyroid gland. Find the disintegration constant λ and the half-life $T_{1/2}$ for this radionuclide.

Hint: linearize the decay law and graph.

Answer: $1.656/h$; $25.1\ min$

t(min)	4	36	68	100	132	164	196	218
R(cts/s) 392.2	161.4	65.5	26.8	10.9	4.56	1.86	1	

3. TR.12.54. The age of the Earth is 4.5 billion years. If the isotope ratio ^{235}U is 0.72% abundant today relative to ^{238}U, what was the ratio of these isotopes when the Earth formed?
The half-lives of the two uranium isotopes are $T_{\frac{1}{2}} = 0.704\ 10^{9}\ y$ for ^{235}U and $T_{\frac{1}{2}} = 4.468\ 10^{9}\ y$ for ^{238}U.

Answer: 30%

4. HR.p1177. A $2.71\ g$ sample of KCl from the chemistry stockroom is found to be radioactive, and it is decaying at a constant rate of $44.90\ Bq$. The decays are traced to the element potassium and in particular to the isotope ${}^{40}_{19}K$, which constitutes 0.0117% of normal potassium. Calculate the half-life of this nuclide.
The molar mass of K is $39.1\ g/mol$ and for Cl is $35.45\ g/mol$.

Answer: $1.25\ 10^{9}\ y$

Nuclear decays and reactions

5. TR.12.33. (modified) Tritium, with half-life $12.33\ y$, is mostly produced for military purposes. [The US stopped producing tritium in 1988 but resumed in 2003.] In 1996 it was reported that the US had $75\ kg$ of tritium stockpiled.

a. If none of it was used by 2003, how much tritium remained and what was its activity? How would it compare with the activity of the same amount of ${}^{239}Pu$, with half-life $24110\ y$ (used as alpha source for power generation)?

b. If the decay product of tritium is ${}^{3}_{2}He$, write the decay reaction of tritium.

c. Tritium can be produced in nuclear reactors by <u>neutron activation</u> of ${}^{6}_{3}Li$, i.e. by bombarding the target with a neutron beam. Write the reaction for producing tritium in this way.

Answer: $50.6\ kg$; $5.71\ 10^{23}/y$; $74.98\ kg$; $5.43\ 10^{18}/y$

6. TR.12.53 Use only Z and A values to calculate the number of α and β particles produced from the decay of ${}^{235}_{92}U$ to its stable end product ${}^{207}_{82}Pb$.
Answer: $7;\ 4$

Radioactive dating

7. YF.p.1458. Before 1900 the activity per unit mass of atmospheric carbon due to the presence of ${}^{14}_{6}C$ averaged about $0.255\ Bq$ per gram of carbon. The half-life of ${}^{14}_{6}C$ is $5730\ y$ and the molar mass of carbon $12.011\ g/mol$.
a. What fraction of the carbon atoms were ${}^{14}_{6}C$?
b. In analyzing an archeological specimen containing $500\ mg$ of carbon, you observe 174 decays in one hour. What is the age of the specimen, assuming its activity per unit mass of carbon when it died was the average value in the air?
Note: $1y = 3.156\ 10^{7}\ s$
Answer: $1.3\ 10^{-12};\ 8019y$

8. HR.p1183. In a Moon rock sample, the ratio of the number of stable ${}^{40}_{18}Ar$ atoms present to the number of radioactive ${}^{40}_{19}K$ is 10.3. Assume that all the argon atoms were produced by the decay of potassium atoms, with a half-life of $1.25\ 10^{9}\ y$. How old is the rock?
Answer: $4.37\ 10^{9}\ y.$

9. TR.12.49 Two rocks have ratios ^{206}Pb/^{238}U of 0.76 and 3.1, respectively.
What are the ages of the two rocks? Did they likely have the same origin? Assume all the lead atoms were produced by the decay of uranium atoms, with half-life $4.47\ 10^{9}\ y$.
Answer: $3.65\ 10^{9}\ y;\ \ 9.1\ 10^{9}\ y.$

10. TR.12.52. If the age of the Earth is 4.6 billion years, what would be the ratio ^{206}Pb/^{238}U in a uranium bearing rock as old as the Earth?
Assume all the lead atoms were produced by the decay of uranium atoms, with half-life $4.47\ 10^{9}\ y$.
Answer: 1.04