Supplement – Nuclear Chemistry

Additional Practice Problems

1. What is the missing particle in the reaction below that results in the formation of ^{14}C in the atmosphere?

$$^{14}_{7}N \quad + \quad ? \quad \rightarrow \quad ^{14}_{6}C \quad + \quad ^{1}_{1}p$$

(a) α-particle
(b) electron
(c) neutron
(d) proton
(e) positron

2. Which of the following processes would enable a nucleus below the belt of stability to increase its neutron-proton ratio?

i. positron emission ii. electron capture iii. α emission iv. β emission

(a) i
(b) ii
(c) iii
(d) iv
(e) i and ii

3. The unstable isotope ^{99}Tc has a half-life of 6.0 hours. What fraction of a given sample would remain after 30.0 hours?

(a) 0.50
(b) 0.25
(c) 0.125
(d) 0.0625
(e) 0.03125

4. The radioactive decay of an unknown isotope is 75% complete in exactly 400 seconds. What is the half-life of the isotope?

(a) 50 sec
(b) 100 sec
(c) 200 sec
(d) 300 sec
(e) 964 sec

5. What one-step reaction would cause ^{201}Hg to decay to ^{201}Au?

(a) fusion
(b) fission
(c) α emission
(d) β emission
(e) electron capture

6. What one-step decay reaction would cause ^{230}Th to decay to ^{226}Ra

(a) α-decay
(b) β-decay
(c) electron capture
(d) positron emission
(e) none of these

7. ^{41}Ca undergoes two decay reactions. The first decay is by electron capture, and the product of this reaction then undergoes alpha decay. What is the final product after the second decay reaction is complete?

(a) Ti
(b) Ca
(c) Ar
(d) Cl
(e) Sc

8. Which of the following is the product formed after ^{14}C undergoes beta emission?

(a) ^{13}Be
(b) ^{12}B
(c) ^{14}N
(d) ^{12}C
(e) ^{16}O

9. The half-life of the radioisotope carbon-11 is 20.4 minutes. What percentage of a given sample would remain after an hour?

(a) 2.94%
(b) 5.28%
(c) 13.0%
(d) 34.0%
(e) 71.2%

10. A rock contains 0.567 mg of lead-206 for every milligram of uranium-238. The half-life for the decay of uranium-238 to lead-206 is 4.5 x 10^9 yr. How old is the rock?

(a) 4.5 x 10^9 years
(b) 1.7 x 10^9 years
(c) 3.36 x 10^9 years
(d) 1.5 x 10^5 years
(e) 3.99 x 10^7 years

11. Given that the mass of a nickel-60 nucleus is 59.9308 amu, determine what is the mass defect of a ${}^{60}_{29}Ni$?

(a) 28.7930 amu
(b) 1.3066 amu
(c) 1.2374 amu
(d) 0.5505 amu
(e) 0.5458 amu

12. The binding energy of ^{60}Co nucleus is 8.206 x 10^{-11} J, what is the mass defect in this nucleus? (The mass of cobalt-60 nucleus is 59.9338 amu.)

(a) 0.4987 amu
(b) 0.3286 amu
(c) 0.8765 amu
(d) 0.5267 amu
(e) 0.5485 amu

Solutions

1C
One way for N-14 to become C-14 is via positron emission. Since the only other product besides C-14 is a proton however, and not a positron, we have to assume that the positron reacted with another sub-atomic particle to become a proton. This is confirmed by the fact that there is a missing reactant we need to identify, and the only reactant we can choose that could react with the positron and become a proton is a neutron.

2E
Below the belt of stability we are neutron deficient, and so a proton must be converted to a neutron to increase stability. This can be achieved by either positron emission or electron capture.

3E
30 hours is equal to exactly 5 half-lives, thus there will be 1/32 (equal to 0.03125) of the original amount left over (after 1 half-life: 1/2, after 2 half-lives: 1/4, after 3 three half-lives: 1/8, after four half-lives: 1/16, after 5 half-lives 1/32).

4C
This question can be solved by just working out how many half-lives are required to achieve 75% decay. One half-life would cause 50% to decay, and the next would cause 25% to decay, which would result in 75% decay. Thus it takes 2 half-lives to achieve 75% decay. Since we're told that the entire process took 400 seconds and we now know that this time equals two half-lives, we can divide by 2 to get 200 seconds as our half-life.

5E
Hg has 80 protons and Au has 79 protons. Since the mass doesn't change we are simply looking for a reaction that reduces the proton number by 1. Either electron capture or positron emission would be acceptable answers, and so we pick electron capture as it's the only one of these two options available.

6A
Only alpha decay can cause the mass to decrease by 4 in one step.

7D
The quickest way to deal with questions like this is to follow the protons.
We start with Calcium, which has 20 protons. First, electron capture reduces proton number by one, bringing us down to 19. Then, alpha decay reduces proton number by 2, bringing us down to 17. Thus the correct answer is chlorine since it has 17 protons.

8C
Beta emission involves the loss of an electron. Therefore, carbon's proton number increases by one transforming it into N.

9C
Considering that after one hour the radioisotope would have experienced a little under 3 half-lives, we can expect the percentage remaining to be close to 12.5%. Remember that after one half-life 50% remains, after two half-lives 25% remains, and after three half-lives 12.5% remains. Since one hour doesn't quite make 3 half-lives, we expect there to be a little more left than 12.5%.

10C
Since it is not stated, we can assume at this point in time there is N_t = 1 mg uranium present; therefore, there is 0.567 mg lead present in the rock. The question is then how much uranium was originally present in the rock if we assume all of the lead that exists comes from uranium decay. Since lead and uranium have different masses, the mass of uranium that decayed must be calculated by multiplying 0.567 mg Pb by 238 U/206 Pb (Mass number ratio), which gave a mass of 0.6551 mg Uranium. Therefore the total amount of uranium originally present was 1.6551 mg, which is value for N_o. Plug this data into the first order rate decay integral equation and solve for t.

11E
To get mass defect we subtract the sum of the 29 protons and 31 neutrons from the actual mass given:
$\Delta m = [(1.0072765 \times 29) + (1.0086649 \times 31)] - [59.9338] = 0.5458$ amu

12E
Use the E=mc2 equation and work backwards. Solve for the mass defect (m), which will be in kilograms. Then, just convert to grams, and finally convert to amu, using the conversion provided on your data sheet: 1g = 6.02×10^{23} amu.