**Nuclear Chemistry Exam Questions**

**From Spring 2001 Semester**

**Useful constants:**

 Avogadro’s number (NA) = 6.022137 x 1023/mol

 mass of proton = 1.007276 amu

 mass of neutron = 1.008664 amu

 mass of electron = 5.485799 x 10-4 amu

 speed of light (c) = 3.0 x 108 m/s

 6.022137 x 1023 amu = 1g

 1 J = 1 kg•m2/s2

 1 eV = 1.602 x 10-19 J

 1 Mev = 106 eV

1) Complete and balance each of the following nuclear reactions.

 a.  Answer: 

 b.  Answer: 

 c. γ Answer: 

d.  Answer: 

e.  Answer: 

2) Predict the most likely type of radioactive decay process for each of the following radionuclides. In each case, decay occurs only via beta emission, alpha emission, or positron emission.

 a.  (All isotopes of thorium are radioactive.) \_\_\_\_\_alpha \_\_\_\_\_\_\_\_\_\_\_

 b.  ( is stable and nonradioactive.) \_\_\_\_\_\_\_beta \_\_\_\_\_\_\_\_\_\_\_\_\_

 c.  ( is stable and nonradioactive.) \_\_\_\_\_\_\_\_\_ positron \_\_\_\_\_\_\_\_\_\_\_

 d.  ( is stable and nonradioactive.) \_\_\_\_\_\_\_\_\_beta \_\_\_\_\_\_\_\_\_\_\_

 e.  ( is stable and nonradioactive.) \_\_\_\_\_\_\_\_positron \_\_\_\_\_\_\_\_\_\_\_\_

3) Write **balanced** nuclear equations for each of the following processes.

1. bombardment of curium-246 (Cm) with carbon-12 produces nobelium-252 (No) and neutrons



1. positron emission by iron-53 (Fe)



1. electron capture by tellurium-111 (Te)



1. alpha emission by lawrencium-259 (Lr)



1. beta emission by platinum-201 (Pt)



4) In each of the following pairs, one of the nuclides is radioactive and the other is stable and nonradioactive. Predict which is radioactive and which is stable, and explain your choice briefly.

1. Y-90 or Zr-90

Zr-90 is nonradioactive and Y-90 is radioactive. This is based on the fact that Zr-90 has a magic number of neutrons (50) and even numbers of both protons (40) and neutrons (50), whereas Y-90 does not.

1. Cr-52 or Cr-49

Cr-52 is nonradioactive and Cr-49 is radioactive. This is based on the fact that Cr-52 has a magic number of neutrons (28), whereas Cr-49 does not.

5) Linen wrapped around the mummy of the great King Perseus of the ancient kingdom of Orangello gave 12.8 disintegrations of 14C per minute per gram of carbon. Assuming that the linen was less than a year old when used in the burial of the king, approximately how many years ago did the old boy die? Carbon from present-day living material gives 15.3 disintegrations of 14C per minute per gram of carbon. The half-life of carbon-14 is 5.715 x 103 years.

 t1/2 = Ln2 k = 0.693 / 5.715 x 103 years = 1.212 x 10-4 yrs-1

 k

Ln [A]t =– kt 🡪 ln ( 12.8 dis/g\* min) = - 1.212 x 10-4 yrs-1 \*t 🡪 t = 1471 years

 [A]o (15.3 dis/g\* min)

6) The decay constant of gallium-67, a radioisotope used for imaging soft-tissue tumors, is 0.00886/hr (hr-1). Calculate the half-life, t1/2, in seconds (s) for 67Ga.

t1/2 = Ln2 k = 0.693 / 0.00886/hr = 78.2 hr

 k

78.2 hr \* 3600 sec/ 1 hr =2.82 x 105 seconds

7) Calculate the mass defect for palladium-106. The atomic mass of the 106Pd nucleus is 105.87824 amu. Account briefly for the difference in mass observed.

A nucleus always weighs less than the individual protons and neutrons from which it is composed The reason why is that energy is lost by the system when nucleons combine. This difference is the mass defect.

Protons: 46 x 1.007825 amu = 46.35995 amu

Neutrons: 60 x 1.008665 amu = 60.5199 amu

Total mass of unbound nucleons = 106.87985 amu

m = 106.87985 amu – 105.87824 amu. = 0.9763 amu

8) Consider the fission reaction in which uranium-235 is bombarded by neutrons.

n + U → Rb + Ce + 3e + 3n

 The atomic masses (in amu) are 235.043924 for uranium-235, 88.912278 for rubidium-89, 143.913643 for cerium-144, 5.485799 x 10-4 for the electron (e), and 1.008664 for the neutron. Calculate the amount of energy released, ΔE ( in kJ), when **one gram** of uranium-235 undergoes this fission reaction.

E = mc2 1 kg = 6.022 x 1026 amu.

 *m*reactant =

9) A sample of phosphoric acid, H3PO4, known to contain a significant amount of radioactive phosphorus-32, was accidentally spilled onto the lab floor. It was suggested by one of the technicians in the lab that the radioactivity could be neutralized by reacting the spilled acid with a base such as NaOH. Do you agree or disagree with this suggestion? Explain your answer.

Disagree. Nuclear reactions take place inside the nucleus and involve changes in the nucleons. Chemical reactions take place outside the nucleus and involve valence electrons. Thus, the reaction suggested by the technician will only neutralize the acidity of the spilled acid, not the radioactivity of the P-32 in it. Nuclear reactions occur regardless of the chemical state of the radioactive atom.