2014 Summer School in Nuclear Chemistry

Sample Lecture Problems with Answers

1. What is the mass of one atom of ^{40}Ca?

6.641E-23 g

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2. What is the mass of 150 atoms of ^{139}La?

3.549E-20 g

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3. How many atoms are in 2.4 g of ^{99}Tc?

1.46E22 atoms

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4. What is the mass of $6.00*10^4$ atoms of ^{3}H?

2.989E-19 g

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5. What is the average atomic mass of copper given the following isotopic composition?
69.17% ^{63}Cu mass = 62.9296 amu and 30.83% ^{65}Cu mass = 64.9278 amu

63.546

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6. Elemental thallium consists of two isotopes, ^{203}Tl with exact mass 202.9723 amu and ^{205}Tl with mass 204.9744 amu. If the average atomic mass of Tl is 204.3833, what is the percent of each isotope in natural thallium?

29.52% 203Tl and 70.48% 205Tl

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7. **A solution contains an unknown amount of Sr which is to be determined by stable isotope dilution analysis. A spike containing 0.5 ng of ^{84}Sr is added to the unknown solution. The natural isotopic abundances of ^{88}Sr and ^{84}Sr in the unknown are 83.698% and 0.462%, respectively. The $^{88}Sr/^{84}Sr$ in the "spiked" sample is determined by high resolution mass spectrometry to be 45.028. Calculate the mass of Sr in the original sample.**

3.58E-8 g

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8. **A 150 mg sample of a meteorite was dissolved in *aqua regia* and the osmium concentration was estimated to be at the ng/g (ppb) level or below. Chemically pure Os could be isolated from the solution but not quantitatively. The isotopic abundances of ^{186}Os and ^{190}Os were measured to be 1.453% and 28.994% by mass spectrometry. A $0.486*10^{-9}$ g sample of pure osmium containing 5.346% ^{186}Os and 22.987% ^{190}Os was added to the unknown solution and mixed thoroughly. Thermal ionization mass spectrometry gave an osmium 190:186 ratio of 8.494 in the spiked sample. What was the original concentration of Os in the meteorite sample? HINT: The spike of pure osmium enriched in ^{186}Os changes the isotope ratio in the sample by increasing the mass of both ^{186}Os and ^{190}Os. The problem can be solved by using two equations with two unknowns.**

6.54E-10 g

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9. **^{15}N enriched atmospheres are important in studying nitrogen fixation by rhizomes. Calculate the number of stages necessary to enrich ^{15}N from its natural abundance of 0.37% to an abundance of 25% if the isotope enrichment process has an enrichment factor of 1.014.**

323 stages

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10. **What would the enrichment factor have to be in order to produce 95% ^{10}B from a feed of natural boron which is 19.9% in ^{10}B in 100 product cycles?**

1.044

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11. **What is the nuclear radius of ^{144}Nd?**

7.39E-15 m or 7.39 fm

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12. What is the nuclear radius of ^{60}Co?

5.48E-15

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13. Calculate the coulombic force between a proton and a ^{56}Fe nucleus that are $1*10^{-14}$ m apart. Express your answer in MeV.

3.74 MeV

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14. Calculate the coulombic barrier between an alpha-particle and a ^{238}U nucleus. Express your answer in MeV.

24.31 MeV

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15. Calculate the value of Q_α for the α-decay of ^{238}U.

4.27 MeV

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16. Calculate the value of Q_α for the α-decay of ^{257}Fm.

6.86 MeV

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17. Calculate the maximum energy of the α-particle emitted by ^{257}Fm.

6.76 MeV

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18. Calculate the value of Q for the β^--decay of ^{90}Sr.

0.547 MeV

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19. Calculate the value of Q for the β^--decay of ^{24}Na.

5.515 MeV

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20. Calculate the value of Q for the β^+-decay of ^{11}C.

0.961 MeV

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21. Calculate the value of Q for the β^+-decay of ^{13}N.

1.199 MeV

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22. What will be the activity of a solution originally containing 15 μCi of ^{146}Pm after 3 years?

10.3 **μCi**

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23. How many years will be required for 5000 Ci of ^{90}Sr to decay to 1 mCi?

647.7 y

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24. If 25.0 mCi of ^{24}Na were shipped Monday at 12:00 noon to be used in an experiment at 10:00 AM on Wednesday, how many dpm of ^{24}Na would be left?

6.59E9 dpm

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25. How many grams of ^{24}Na would be left when the experiment starts?

3.40E-10 g

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26. **^{50}V is 0.250% of natural vanadium. What is the activity of 1.0 grams of V in terms of dpm/gram?**

2.78E-4 dpm

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27. What is the mass of 2.5 mCi of "carrier free" ^{54}Mn?

3.23E-7 g

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28. How many grams of ^{234}Th would be in secular equilibrium with 100 grams of ^{238}U?

1.45E-9 g

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29. Calculate the ratio of ^{238}U to ^{210}Pb in a sediment sample that has attained secular equilibrium.

Ration 238U to 210Pb is 2.00E8

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30. ^{250}Cm has a half-life of about 9000 years and decays approximately 86% by spontaneous fission, 8% by α-decay and 6% by β--decay. Calculate the half-lives of each of these modes of decay.

1.5E5 y

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31. **^{226}Pa decays by a-decay with a 2.43 min half-life and by EC decay with a 6.92 min half-life. Calculate the overall half-life for the decay of ^{226}Pa?**

1.798 min

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32. **How many ion pairs are formed in air by a 5.4 MeV alpha particle? (assume a w value of 34 eV/ion-pair)**

1.59E5

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33. How much energy is lost when a particle interacts with helium to form $2*10^3$ ion pairs? Express your answer in joules.

1.09E-14 joule (0.068 MeV)

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34. The mass attenuation coefficient for 1.0 MeV γ-rays in lead is about 0.071 cm^2/g. Calculate the thickness of lead (in cm) necessary to reduce a 1.0 Ci source to 1.0 mCi.

8.6 cm

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35. Calculate the Compton edge for the 0.51 MeV γ-ray emitted by ^{22}Na.)

0.34 MeV

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36. A sample counted for 15 minutes gave 8,486 total counts. A 30 minute background count registered 1153 counts. Calculate the count rate of the sample alone with its standard deviation and its probable error.

551.3 ±6.3 cpm (probable 50% error ±4.3 cpm)

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37. If only 30 minutes of counting time are available, calculate the desirable division of time between sample and background for minimum error if the background is approximately 8 cpm and total rate 25 cpm. What will the standard deviation for the sample be, expressed as a percentage error?

Background 10.8 min and sample 19.2 min

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38. The following counting data were collected per minute with one sample: 3308, 3277, 3411, 3080, 3580, 3425, 3207, 3436, 3328, 3363 counts. Should any of these counts be rejected if it is desired to calculate a good average count rate?

3342±137 cpm (all counts should be retained)

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39. Calculate the total number of counts that must be collected in each case for a count rate of 500 cpm to give a probable error of 0.1%.

~455,000 counts

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40. Two successive counts in a proportional counter of the same sample for the same interval gave values of 5440 and 5600. Can the counter be considered to be operating normally? What would be the most probable conclusion if the two counts were 5440 and 5750?

For 5600 counts, >99.7% probably OK -- for 5750 counts, <<0.3% likely to be OK

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41. An unknown sample registers 5050 cpm using LSC. A known standard of 8140 dpm is added to the sample and upon recounting, the sample registers 11240 cpm. The background is already subtracted. What is the counting efficiency of the system and what is the activity (in dpm) of the unknown?

76% efficiency gives a sample rate of 6641 dpm

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42. Six aliquots of tritiated water were counted with LSC and the times in minutes required to register 100 counts were: 18.2, 17.8, 18.0, 13.1, 18.5, and 18.7. The background gave 22 counts in 15 min. Calculate the average count rate and its standard deviation.

count rate = 3.99 ± 0.63 cpm {omitting measurement 4}

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43. A 2.5 mL sample of an aqueous solution containing 0.37 microCuries per mL of tritium is injected into the bloodstream of an animal. After allowing sufficient time for complete circulatory mixing, a 1.0 mL aliquot of blood is removed and found to have an activity of 1530 dpm of tritium. From this, calculate the blood volume of the animal.

1.34 L

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44. Twenty (20) mL of an aqueous solution containing 0.01 g of iodine tagged with ^{129}I giving a count rate 25,000 dpm is equilibrated with 10.0 mL of CCl_4. Using the distribution coefficient, K_d = [organic phase]/[aqueous phase] = 20. Calculate the weight of iodine in each solvent at equilibrium and the count rate in each solvent at equilibrium.

organic phase = 0.900 mg/mL (2250 cpm/mL) ; aqueous phase = 0.050 mg/mL (125 cpm/mL)

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45. A counting system has a background counting rate of 0.52 cpm. If samples are normally counted for 1 hour, what is the LLD (lower limit of detection) at the 95% confidence level.

LLD = 343 counts or 5.72 cpm

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46. A liquid scintillation counting system has a LLD for ^{3}H of 1.5 cpm/mL. Express the LLD in terms of fCi per liter.

LLD = 676 fCi/mL

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47. In a tracer experiment, it was desired to have a total of ~1000 cpm for each sample. If the percent recovery of the radioisotope spike was about 15% and the counter efficiency was estimated to be about 25% for this radiation, what count rate spike should be used in each experiment? What volume of a 1.0 mCi/mL stock solution should be used?

~27,000 dpm of activity per experiment; The stock solution: 1.0 mCi/ml =1.0 µCi/µl or 1.0 µCi/µl = 2.2 x 10^{6} dpm/µl To provide 2.7 x 10^{4} dpm of tracer requires an aliquot 1.2 x 10^{-2} µl of the stock solution. Obviously, a more dilute stock should be used. Dilute the stock 1:10,000 or ~0.010 mL (10 µl of stock) diluted to 10 mL - now the spike would be between 10 - 15 µl

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48. Fifty (50) mL of an aqueous solution containing tagged with ^{233}U giving a count rate 100,000 cpm is equilibrated with 50 mL of hexane containing tri-n-butyl phosphate as the extractant. If the count rate of the organic phase after equilibration is 1543 cpm/mL, what is the K_d for the extraction of uranium under these conditions?

Kd = 3.4