Chemistry 985

Fall, 2o19 Exam # 1 **OPEN BOOK**
Distributed: Thurs., 10 Oct. 19, 8:30AM Due: 10 Oct 19, 10:00AM

Some constants: $q_e$ 1.602x$10^{-19}$ Coul, $\epsilon_0$ 8.854x$10^{-12}$ F/m
h 6.626x$10^{-34}$ J-s, c 299 792 458 m/s, 1 atm = 760 Torr = 101,325 Pa

1. In a recent seminar at the NSCL the speaker indicated that individual pulses of 230 MeV protons were used in radiation therapy to deliver 4 J/s/cm$^3$ in 20 microseconds into a volume of approximately one cubic centimeter.

   (a) (5 pts) The speaker indicated the the beam intensity was 160 pC/pulse. Calculate the number of protons in each pulse.

   (b) (5 pts) What is the instantaneous power in Watts of one single proton pulse?

   (c) (5 pts) What is the dose in Gray that one pulse would deliver to the one cubic centimeter if it is (liquid) water? Note that (liquid) water is the phantom material of choice for both reference and relative dosimetry measurements in radiation therapy.

2. A research group at Lawrence Berkeley National Laboratory is a leading developer of new inorganic crystals for gamma ray detection. The table below was taken from their website [*https://ipo.lbl.gov/lbnl2711/*] and gives some of the measured properties of two materials that they produced. Answer the following questions based on the data in the table.

   (a) (10 pts) Determine if the reported number of photons/MeV reported in the table for the BaBrI (IB-2720) is consistent with the reported energy resolution. This measurement was made with a $^{137}$Cs gamma ray source.

   (b) (5 pts) Compare the overall suitability of the $Ba_2CsI_5$ (IB-2751) material to the BaBrI (IB-2720) material for gamma-ray measurements in nuclear science based on this data.

| Reference No. | IB-2711 | IB-2720 | IB-2751 | IB-2767 |
|---|---|---|---|---|
| *Representative Composition* | $Ba_3(PO_4)_2$ | BaBrI | $Ba_2CsI_5$ | BaBrISr |

**TABLE 2:**

**Performance Characteristics of IB-2720 and IB-2751**

| Characteristics | IB-2720 | IB-2751 |
|---|---|---|
| *Mean luminosity(photons/MeV of absorbed gamma radiation)* | 87,000 | 97,000 |
| *Energy resolution(full width half maximum of the 662 keV absorption peak)* | 4.3% | 3.8% |
| *Density* | 5 g/cm$^3$ | 5 g/cm$^3$ |
| *Decay time (for more than 80% of the emitted light under X-ray excitation)* | Less than 500 nsec | 1.2 msec |

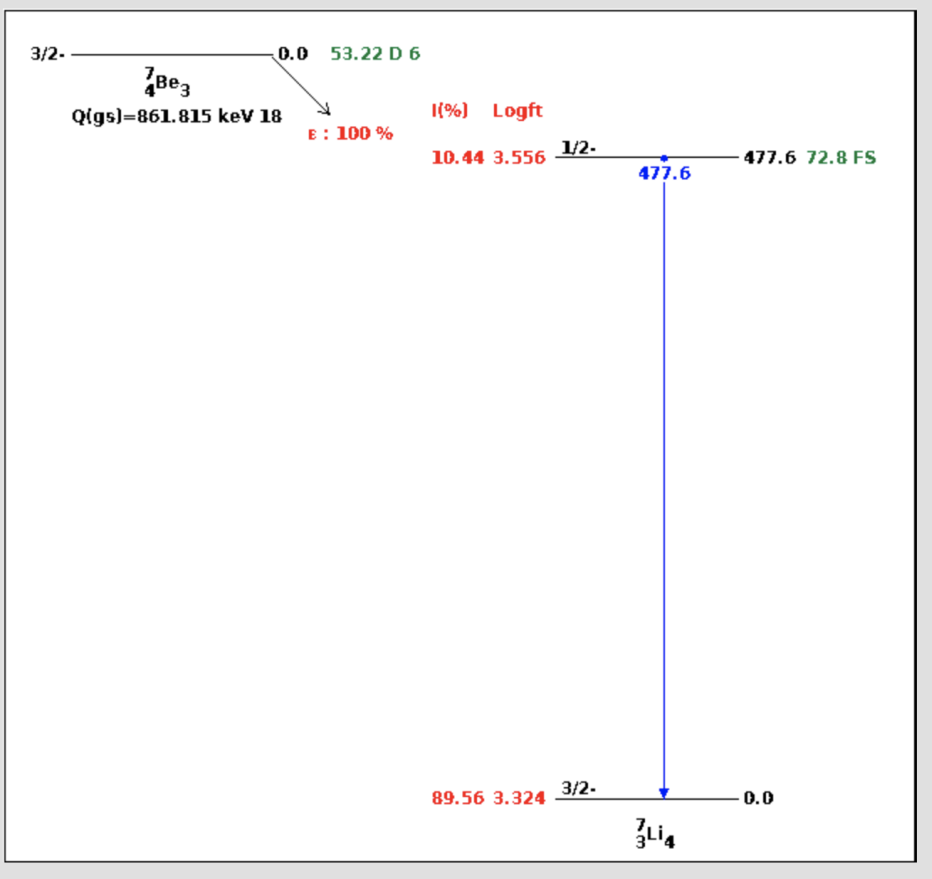
3. Plastic scintillators are sometimes used to detect beam particles at the NSCL. For example, a 100 MeV/A $^{40}$Ar beam particle has a range of 9.5mm in BC-400 ($C_9H_{10}$) plastic material and typical beams have a radius of 5 mm at the end of the beam line.

   (a) (10 pts) The text indicates that radiation damage begins in plastic scintillators at about $10^{12}$ MeV/g. How many beam particles would deliver this equivalent dose to the scintillator under these conditions?

   (b) (5 pts) Do you expect the damage to be uniform over this volume or not? Explain.

- Continue -

4. A student wanted to measure the amount of $^{7}$Be produced in a beryllium metal target right at the end of a production run at the NSCL. The beam spot was only 1 mm in diameter at the production target (so that it can be considered a point source for this problem). A detector that was sensitive to gamma rays, with a circular active area with a 5 cm diameter, was placed 10 cm from the source for a 100.0 second measurement. The intrinsic efficiency of the detector is 0.5 and the (non-paralyzable) system dead time was 10.0 $\mu$s. The observed counting rate of the expected photon was 3x10$^{4}$/s under these conditions.




(a) (5 pts) What is the true counting rate?

(b) (10 pts) What is the source strength in Bq?

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5. Give a concise and accurate answer to each of the following five questions.

   (a) (3 pts) Describe why gas-filled ionization counters for measuring environmental radiation doses from external sources are generally tightly sealed but gas-filled ionization counters for charged particles always flow the counter gas.

   (b) (3 pts) There is a large effort these days to develop (new) organic scintillators that can discriminate between signals produced by neutrons and photons. Give an important reason that there is no substantial effort to develop (new) inorganic scintillators for neutron detection?

   (c) (3 pts) Describe why only electrons are avalanched in proportional counters.

   (d) (3 pts) Describe why Piranni vacuum gauge can not provide a valid pressure reading at very low pressures (i.e., less than 10 mbar).

   (e) (3 pts) Describe why it is important to close a valve between an oil-filled mechanical pump and an evacuated chamber before the pump is turned off.

*ALL DONE*