Nuclear Chemistry Cumulative Examination
Wednesday, 19 March 2o14

This examination is concerned with the general properties of vacuum systems and radiation detectors and related equipment as discussed in Chem-985 and in the Knoll's textbook Radiation Detection and Measurement.

The exam has a total of 100 points.

1. (25 points, 5 each) Provide **concise** and accurate answers to the following five questions about vacuum equipment.

   (a) Give a general description of the operation of a Piranni vacuum gauge (i.e., what is measured and how is that sensitive to pressure).

   (b) Describe the purpose of the filament in a standard (Bayard-Alpert) hot-cathode vacuum gauge.

   (c) What is the most likely (highest pressure) gas and what is its source in a sealed metal beam pipe (no leaks) immediately after the air is removed and the pumping system has just reached its base pressure?

   (d) How does the conductance of a round pipe scale with the radius of that pipe in the laminar flow region?

   (e) What is the effective speed of a high vacuum pump, S=250 L/s for air, that is connected to a vacuum chamber with a straight pipe with a molecular-flow conductance of 150 L/s for air?

2. (15 points, 5 points each) Give a concise and accurate answer to each of the following short questions about neutron detectors that are used extensively in nuclear science.

   (a) The Dept. of Homeland Security has cornered the market on ^{3}He that is the "active ingredient" in gas-filled neutron detectors. Give a concise explanation of the mechanism for neutron detection with ^{3}He gas.

   (b) The high cost and low availability of ^{3}He has driven the exploration of plastic scintillators for neutron detectors. Give a concise explanation of the mechanism of neutron detection with plastic scintillators.

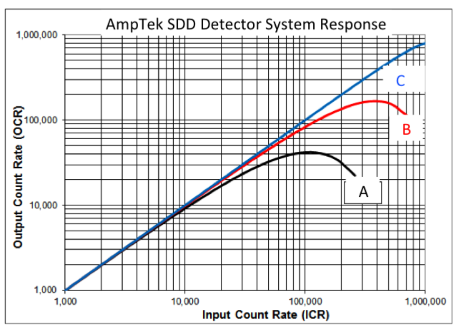
   (c) A recent manuscript reported using a "total absorbing" detector to measure the neutron flux in a particular experiment. Explain why there is not such thing as a "totally absorbing detector" for neutrons.

3. (20 points) A gamma-ray detector in use at the NSCL has a photopeak efficiency of 50% and a cross sectional area of 10 cm^2. What is the expected counting rate for the 0.662 MeV peak from a 1μCi ^{137}Cs point source (one photon per decay) at a distance of 50 cm from one of these detectors?

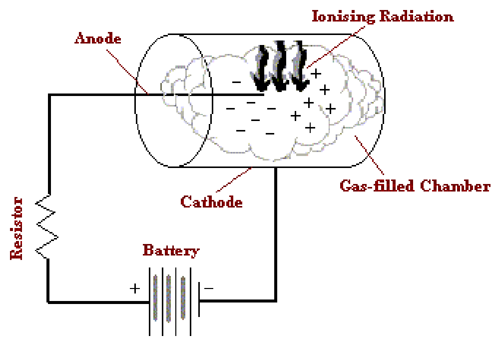
4. (20 points) The following figure shows the response of a commercial x-ray spectrometer system as a function of incident x-ray rate with three different "user options." The options are labeled A, B and C for our purposes.

   (a) (10 point) Based on the information for Option-A in the figure, is this system paralyzable or non-paralyzable based on the information in the figure? Explain your answer.

   (b) (10 points) Based on the Interval Distribution for the time distribution of random events, describe the most likely time difference between two random decays of a radioactive source.



5. (20 points) Consider the two figures shown below that were found on the web for radiation detectors. (a) Explain why the figure on the left is too simple and will never be able to detect (typical strength) radiation sources. (b) On the other hand, how can the device on the right provide a reliable measurement of neutrons even in the presence of strong gamma-ray sources?


Ionising Radiation
Anode
Gas-filled Chamber
Cathode
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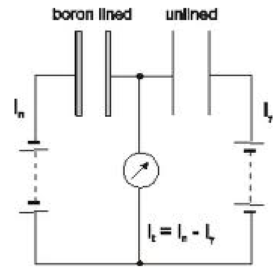
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