Chemistry 985

Fall, 2o17 Exam # 2 **Take Home**
Distributed: Mon., 4 Dec. 17, 9:00AM Due: 5 Dec. 17, 9:00AM

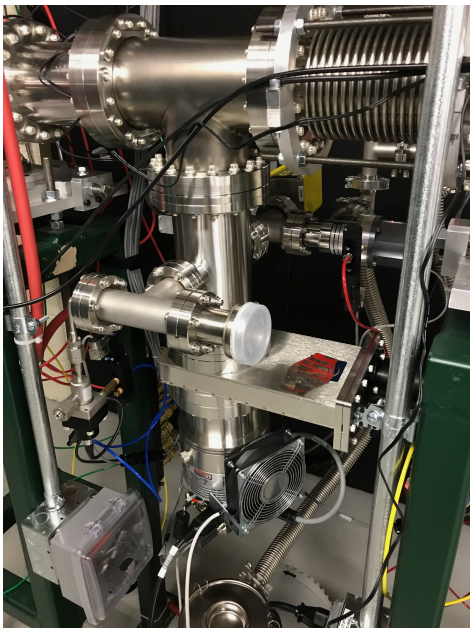
Please work independently and show work for full credit.
This exam has FOUR pages and 100 points total.

1. This question refers to the photographs shown below of some vacuum equipment recently installed on the "D" beam line at the NSCL. The (horizontal) beam line is pumped by an Agilent TwisTorr 304FS with a ConFlat 6 inch OD flange with the straight (vertical) pipe with a gate valve connected directly to the pump.

   (a) (5 points) Estimate the effective pumping speed of this pump at the end of the 24 inch long straight pipe with a gate valve (MDC-301004) both of which have ConFlat 4 inch ID / 6 inch OD flanges.

   (b) (2 points) In steady-state the foreline gauge (Super Bee) reads 3.00 mtorr. What the lowest pressure you could expect under these conditions based on the pump specifications?

   (c) (3 pts) The HV gauge (Hornet) reads 6.8E-8 torr in steady-state, what is the off-gas load, Q, coming from the beam line?



2. (10 pts) A thin plastic scintillator (BC-400 material) at the A1900 Focal plane position provides a time-of-flight "start" signal for various experiments at the NSCL. Based on the thickness, I estimated that a fragment deposits about 0.50 MeV of energy in the scintillator. The plastic scintillator is held in an adiabatic light guide that collects the light from the plastic foil and transmits it to the photocathode of a photomultiplier tube (assume for simplicity the PMT is a Hamamatsu 1306 operated near it's recommended voltage of 900 V). What is the minimum fraction of light transmitted by the light guide to the PMT in order to detect these signals if the electronic counting circuit attached to the PMT has a threshold of eighty photoelectrons?

3. (10 pts) What is the expected resolution of a pulse created by depositing 10.0 MeV into a gas ionization chamber if the Fano factor for P-10 gas is 0.21?

4. A student setup a system to measure the rate of decay of a sample of ^{60}Fe produced with the A1900 using the γ ray following its beta decay. The ^{60}Fe source was placed in directly front of a HPGe detector with an especially thin beryllium window. The total efficiency of the detector was found to be 7.5x10^{-2} by measuring the low energy photon from ^{241}Am under exactly the same conditions.

   (a) (3 pts) What is the ^{60}Fe source strength in Bq if the counting rate in the photopeak was only 2.0/s?

   (b) (2 pts) Which style of germanium crystal would be better to use in this case, a true coax or a bulletized closed-end and why?

   (c) (5 pts) What is the random summing correct to this measurement in this setup if the total coincidence resolving time of 4μs and the total counting rate in the detector due to background was 2000/s? (You know, of course, that true coincident summing is not possible with this source, right?)

5. The following text was found in a recent advertisement in the CERN Courier by the Cremat Corporation.
   "**Charge sensitive preamplifiers - perfect for radiation detection.** *Cremat's charge sensitive preamplifiers (CSPs) can be used to*

readout signals from radiation detectors (e.g., Si, CdTe, CZT), scintillator-photodiode detectors, avalanche photodiodes, ionization chambers, proportional counters and photomultiplier tubes. We also have amplifiers for SiPM photodiodes."
I believe that we discussed the operation of all of these detectors ...

(a) (4 pts) Briefly describe the operating principles of a CZT detector and what radiation it is generally used to detect.

(b) (4 pts) Briefly describe the operating principles of a SiPM and what radiation it is generally used to detect.

(c) (4 pts) Briefly describe the operating principles of a scintillator-photodiode detector and what radiation it is generally used to detect.

(d) (4 pts) Briefly describe the most significant difference between an ionization chamber and a proportional counter.

(e) (4 pts) Notice that they indirectly indicate that different preamplifiers will be necessary for different devices. This company prides itself on providing tiny, plugin preamplifiers. Briefly explain why different preamps are necessary.

6. The new FRIB safety system considered using a series of radiation detectors that each contain (1): a Boron-lined proportional counter in the center of (2) a ten inch diameter nylon cylinder with (3) a cadmium sheet surrounding the nylon. An electronic circuit supplies 750 V to the tube and only records electronic pulses above a certain threshold without regard to pulse height.

   (a) (2 pts) Briefly explain what type of radiation this device is sensitive to, does it discriminate against other types?

   (b) (6 pts) Briefly explain the role of each of the three numbered components.

   (c) (2 pts) Briefly explain why the pulse-height above the threshold can be ignored in this measurement.

7. Provide short answers to the following general questions (a to f):

(a) (5 pts) Bipolar pulses have two significant differences with respect to unipolar pulses that are processed in analogue circuits, one with respect to charge measurement and one with respect to time measurement. Describe these two differences.

(b) (5 pts) Scientists that use PMT's often prefer to use negative high voltage (HV) for pulse processing but scintillation detector manufacturers prefer to use positive high voltages. What is the advantage of using negative as opposed to positive HV for pulse processing? What is the advantage of using positive as opposed to negative HV for detector manufacture?

(c) (5 pts) The backscatter peak is an "artifact" that appears in gamma-ray spectra that one would prefer to avoid. What causes this peak and how can it be minimized?

(d) (5 pts) Escape peaks are "artifacts" that appear in gamma-ray spectra that one would prefer to avoid. When and how are these peaks created and how can this problem be minimized?

(e) (5 pts) Briefly explain why radiation detector signals (either analog or digital) need to be "shaped" before measurement.

(f) (5 pts) Modern ADC's for nuclear signal processing generally oversample the signal and apply a sliding scale smoothing. What is the maximum valid channel number from a 14-bit ADC with an 8-bit sliding scale?