

Chemistry 985

Fall, 2017

Exam # 1 **OPEN BOOK**

Distributed: Mon., 17 Oct. 17, 8:30AM

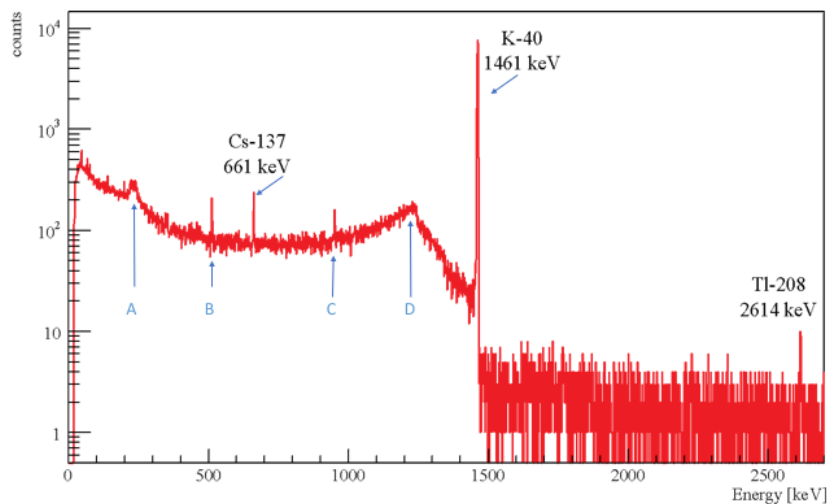
Due: 17 Oct. 17, 10:00AM

Some constants: q_e 1.602×10^{-19} Coul, ϵ_0 8.854×10^{-12} F/m
 h 6.626×10^{-34} J-s, c 299 792 458 m/s, 1 atm = 760 Torr = 101,325 Pa

1. The figure below was taken from the UC-Berkeley website describing low background counting of wild fish:

<https://radwatch.berkeley.edu/salmon>

The focus of the work was measuring relatively short-lived fission products such as ^{137}Cs in the environment. They state that “All samples were counted in the Low Background Facility, on a High Purity Germanium (HPGe) detector. [a very high resolution device to measure gamma rays] This detector is set up to be a very low background system, which allows it to detect very small amounts of radioactivity as compared to other systems. It is in a laboratory space constructed of very thick, low-radioactivity concrete and is equipped with an active veto system to reduce cosmic-ray muon induced backgrounds. ”



The strongest signal in the detector is due to the single photon from the naturally occurring radioactive decay of ^{40}K . The signal from the decay of the ^{137}Cs fission product at 661 keV was also marked by the group. The authors report that the amount of ^{137}Cs in the 0.630 kg sample of fish was 0.14 ± 0.01 Bq/kg (one sigma).

- (a) (4 pts) Clearly and specifically identify the components in the spectrum that are marked as A, B, C, and D.
 - (b) (6 pts) Given the reported activity and uncertainty, make an estimate of the length of time that this sample had to be measured to obtain the reported statistical accuracy.
2. The XP2020 photomultiplier is a very widely used two-inch diameter device with a very high gain. A technical data sheet for the XP2020 photomultiplier is attached at the end of this exam. Answer the following questions based on some of the information in that data sheet.
- (a) (5 pts) What is the reported “typical” quantum efficiency of this PMT at a wavelength of 420 nm?
 - (b) (5 pts) Make an estimate of the value of δ for this tube operating with voltage divider “A” under “Typical” conditions?
3. The device shown in the photograph below has an aluminum vacuum chamber with an internal volume of 24 in x 24 in x 4 in (2304 cubic inches) or 37.76 liters. It is rough-pumped with an Agilent TriScroll 300 and then an Agilent TV-551 turbomolecular pump with an ISO-160 flange is used to attain the ultimate low pressure. Some information from the technical specifications of the TriScroll and TMP, respectively, is shown below.
- (a) (3 pts) Make an estimate of how long it will take to reach the base pressure of the rough pump.
Hint: $Q = P S = -d(PV)/dt$ and $P S = -V dP/dt$ for a closed system. This leads to $P(t) = P_o e^{(-St/V)}$ for constant S.
 - (b) (2 pts) What is the theoretical base pressure of nitrogen for this pump combination based on the information in the technical specifications? Specify your dimensions.

Technical Specifications

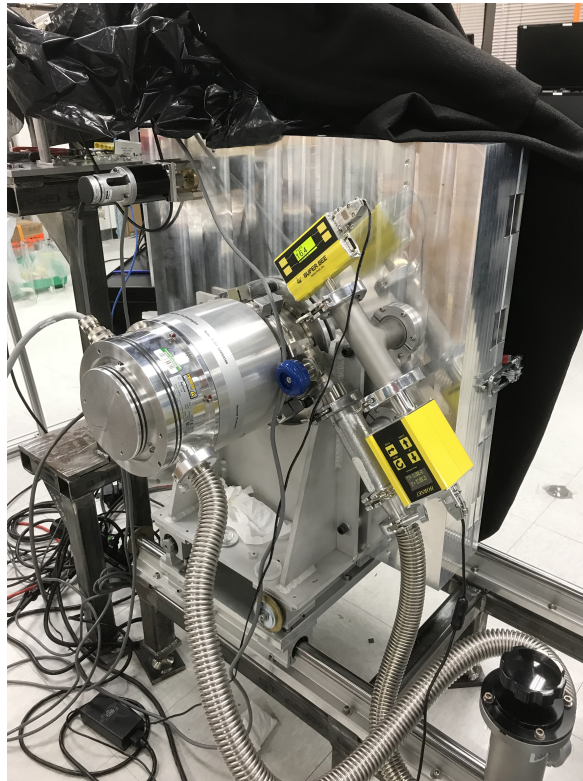
Pumping speed	60 Hz 250 l/m, 15 m³/hr, 8.8 cfm
Ultimate pressure	1.3×10^{-2} mbar (1.0×10^{-2} Torr)
Maximum inlet pressure	1.0 atmosphere (0 psig)
Maximum outlet pressure	1.1 atmosphere (1.5 psig)
Inlet connection	NW25

Technical Specification

Tab. 3 Technical Specification

CHARACTERISTIC	TV 551	
Pumping speed (with inlet screen)	CFF 6":	CFF 8"/ISO160:
N ₂ :	350 l/s	550 l/s
He:	450 l/s	600 l/s
H ₂ :	450 l/s	510 l/s
Compression ratio		
N ₂ :	1×10^9	
He:	1×10^7	
H ₂ :	1×10^6	

- (c) (5 pts) Make an estimate of the base pressure after 1 hour of pumping for this chamber if it is fabricated from aluminum that has a $q = 8.5 \times 10^{-6}$ Pa-m/s at $t = 1$ hour. Specify your dimensions. Note that the TMP is essentially mounted directly onto the vacuum chamber.



4. (6 pts) The confirmation in 2013 of Element 115 claimed to have measured 30 atoms in a “three week run.” Estimate the probability that this experiment went 1 day without observing an event.
5. Give short answers to the following questions.
 - (a) (2 pts) Describe the physical basis of the Fano factor for gas ionization counters.
 - (b) (2 pts) Describe when true coincident summing can be ignored in a gamma ray measurement and why.
 - (c) (2 pts) What is the Bragg Peak and where is it visible?
 - (d) (2 pts) The neutron walls at the NSCL use NE-213 liquid scintillator to detect neutrons in the presence of gamma rays. What is the physical basis for separating these two kinds particles by these detectors?

- (e) (2 pts) Describe what physical process forms (creates, causes, is responsible for) the output signal in a gas-filled proportional counter with a central wire anode.
- (f) (2 pts) What is the difference between the total efficiency and the intrinsic efficiency of a radiation detector?
- (g) (2 pts) What is the physical basis for avoiding using flexible (corrugated) tubes to make high vacuum connections?

Photomultiplier

XP2020

12-stage
51mm (2"), Round tube



Application

- ✓ Energy physics

Features

- ✓ Very Fast
- ✓ Very low noise
- ✓ Good linearity

Description

Window material	Borosilicate glass
Photocathode	Bi-alkali
Refr. Index at 420nm	1.48
Multiplier structure	Linear focused

Photocathode characteristics

	Min	Typ	Max	Unit
Spectral range :		270-650		nm
Maximum sensitivity at :		420		nm
Sensitivity :				
Luminous :		70		μA/lm
Blue * :	7.5	10		μA/lmf
Radiant, at 420nm		80		mA/W

Characteristics with voltage divider A

	Min	Typ	Max	Unit
Gain slope (vs supp. Volt., log/log)		9		
For a gain of		3x10 ⁷		V
Supply voltage *	1750	2000	2600	V
Anode dark current *		10	100	nA
Background noise *		900	2500	cps
Single electron spectrum resolution		70		%
Peak to valley ratio		2.5		%
Pulse amplitude resolution for ¹³⁷ Cs		7.2		%
Gain halved for a magnetic field of :				
Perpendicular to axis "n" :		0.15		mT
Parallel to axis "n" :		0.12		mT

For a supply voltage of : 2000V

	Min	Typ	Max	Unit
Linearity (2%) of anode current up to :		25		mA
Anode pulse :				
Rise time :		1.6		ns
Duration at half height :		3.7		ns
Transit Time :		28		ns

Recommended Voltage Divider

Type A for maximum gain

K	G	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	A	(total : 17)
1.2	2.8	1.2	1.8	1	1	1	1	1	1	1	1	1	1	1	

Type C for linearity

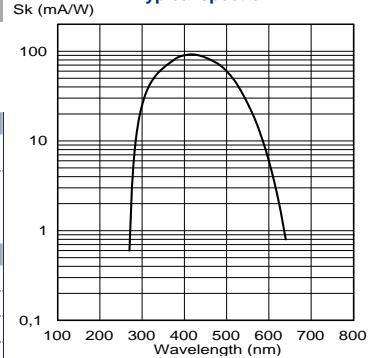
K	G	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	A	(total : 21.5)
1.2	2.8	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5		

* characteristic measured and mentioned on the test ticket of each tube

PHOTONIS

07/08/2007

Typical spectral



Typical gain curve

