

RANGE OF ALPHA PARTICLES IN GAS

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PHYS 403

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ABSTRACT

1 Introduction

$$-\frac{dE}{dx} = \frac{4\pi k_0^2 z^2 e^4 n}{mc^2 \beta^2} \left[\ln \frac{2mc^2 \beta^2}{I(1 - \beta^2)} - \beta^2 \right] \quad (1)$$

$$\frac{dE}{dx} = \frac{k}{E} \Rightarrow R_0 = \frac{E_0^2}{2k} \quad (2)$$

$$X_{\text{eff}} = \frac{D \cdot p}{P_{\text{atm}}} \quad (3)$$

2 Procedure

2.1 Experimental Setup

$$E(\text{MeV}) = 2.26 \times 10^{13} \cdot C_1 \cdot V_{\text{pulser}} \quad (4)$$

Pulser output measured under loaded conditions (93 Ohm cable + 93 Ohm termination at scope).

Pulser settings: 1 kHz frequency, 0.330V offset, 5 microsec width, 5 ns edge. Scope: Ch1 vertical 0.200 V, trigger 0.3 V; Ch2 vertical 2V, time scale 4 microsec.

MCA settings for all measurements: - 3 dB attenuation - 1024 ADC Gain - 10V maximum input voltage - 40V detector bias

Collected calibration spectra at 12 pulser voltages (15 s each), ranging from 0.035 V (0.32 MeV equivalent) to 0.575 V (5.32 MeV equivalent). Determined centroid channel for each peak.

Calibration data:

Linear fit: Channel = $m * \text{Energy} + b$, with $R^2 = 0.9997$. This confirms the system is linear and properly calibrated.

Include calibration plot figure here

2.2 Measurement Procedure

At atmospheric pressure, moved source away from detector until counts disappeared completely. Source disappears at 108 mm on the scale (at trigger 100 mV/div, STP). Locked source at this position (108 mm) for all subsequent measurements.

Table 1: Energy calibration data

Pulser Voltage (V)	Equiv. Energy (MeV)	Centroid Channel	Std (channels)
0.035	0.324	59.04	0.85
0.075	0.694	124.18	0.85
0.125	1.157	208.89	1.59
0.175	1.620	292.37	2.80
0.225	2.082	375.56	1.62
0.275	2.545	453.39	1.60
0.325	3.008	542.05	4.30
0.375	3.471	618.12	3.34
0.425	3.933	708.89	1.60
0.475	4.396	783.09	0.85
0.525	4.859	875.60	6.20
0.575	5.321	953.50	0.87

Source-to-detector distance D: determined from the 108 mm scale reading and the chamber geometry (see Fig. 6 of lab manual). Need to compute actual separation.

For each gas, varied chamber pressure and recorded MCA spectra. Collection time: 45 s per spectrum (initially tried 15 s but data was too noisy). Pressure measured with digital manometer, accuracy +/- 0.1 mmHg.

After collecting each spectrum, recorded: - Chamber pressure (mmHg) - Approximate peak channel (centroid) - Total counts in the peak

Converted channel \rightarrow energy using the calibration fit. Computed $X_{eff} = D * p / P_{atm}$ for each pressure point. Computed E^2 for E^2 vs X_{eff} analysis.

Pressure uncertainties: standard deviation of pressure during each 45 s acquisition was recorded for each trial.

2.2.1 Air

Measured at 16 pressures from 54.8 to 765.1 mmHg. At 765.1 mmHg: no counts detected (beyond range). At 721.2 mmHg: barely visible, channel 56, only 54 total counts. At 674.9 mmHg and below: clear peaks with 1000–1200 counts per 45 s. Took additional high-pressure points (686.6, 700.8, 711.9 mmHg) for better resolution near the cutoff where counts drop off.

Also collected distance-variation data at atmospheric pressure: source moved from 94 mm to 106 mm in 2 mm steps (8 points).

2.2.2 Helium

Flushed chamber with helium. Some initial issues with vacuum controls after flushing, but self-corrected after a few trials.

Measured at 19 pressures from 50.9 to 2000+ mmHg. Helium has much longer range than air – needed to go to pressures well above atmospheric (up to 2000 mmHg) to see significant energy loss. At 50.9 mmHg: observed clipping in MCA; this data point is suspect. Even at 2000+ mmHg, peak was still at channel 624 (significant remaining energy).

2.2.3 Argon

Measured at 16 pressures from 50.4 to 782.0 mmHg. At 782.0 mmHg: only 1 count detected (beyond range). At 770.8 mmHg: channel 50, only 40 counts – near the cutoff. Observed clipping at around channel 47 (affects 770.8 and 759.6 mmHg data). At 726.4 mmHg: 1987 total counts (unusually high – collected for longer or pressure was stable at a point with high transmission).

Argon has shorter range than air due to higher Z (Z=18).

2.2.4 Nitrogen

Measured at 24 pressures from 50.8 to 782.3 mmHg. At 782.3 mmHg: only 1 count (beyond range). At 749.4 mmHg: 2 counts. At 727.8 mmHg: 17 counts. Gradual onset.

Took many additional points around 250–440 mmHg and 650–730 mmHg for better resolution in regions of interest.

NOTE: Possible outliers at 420 and 256 Torr. Tested many other pressures around these and concluded these points were likely affected by outside variables. Nitrogen range is similar to air (expected, since air is 78% N₂).

3 Data Analysis and Results

4 Discussion and Conclusions

References