Analyzing radioactive decay of multiple samples with different half lives.

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1 Methods and Procedure

Background Radiation A Geiger counter was set up in the laboratory with no radioactive sample present. Particle count measurements were taken for every 20 second interval and this was repeated for 1200 seconds (60×20 second intervals). The data collected in this portion of the laboratory was used as a baseline measurement for the background radiation in the laboratory.

Experiment 1 (Barium Sample): A sample of Barium-137 was then placed near the Geiger counter. Particle count measurements were taken again over the same intervals as the background radiation measurements (60×20 second intervals).

Experiment 2 (Fiesta Plate Sample): A fiesta plate with a coating that contains uranium was then placed near the Geiger counter. The same particle count measurements were again taken for 1200 seconds, however for this experiment, 3 second intervals were used (400×3 second intervals).

2 Results

Note: All curve fitting regression values were calculated using the curve_fit function from the scipy.optimize. Referenced functions, equations and calculations are detailed in the **Appendix** section in addition to the raw data and calulated uncertainties.

Experiment 1

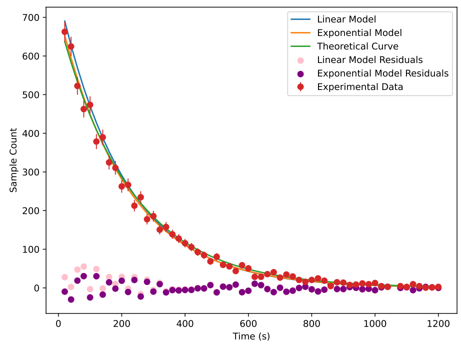

Figure 1: Particle counts over 20 second interval with mean background radiation subtracted vs time for a sample of Barium-137. Linear, exponential and theoretical half life model regressions are included. Residuals for the linear and exponential models are included.

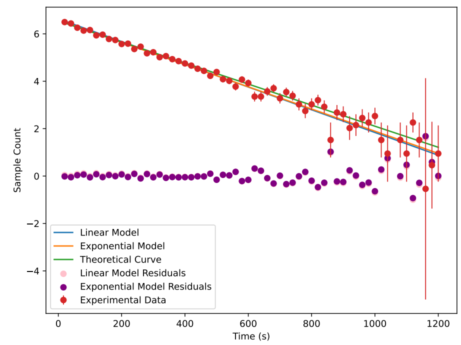

Figure 2 Linearized particle counts over 20 second interval with mean background radiation subtracted vs time for a sample of Barium-137. Linear, exponential and theoretical half life model regressions are included. Residuals for the linear and exponential models are included.

All plotted values have had the mean background radiation measured in the laboratory subtracted from them (approximately 3.42). One measurement for the interval $1040 - 1060$ was removed from graphs since it is outside the log domain. This is discussed further in the analysis section.

Curve fitting

Three curve_fit regressions were performed on the data using an exponential model, a linear model and a model based on the theoretical half life of Barium-137. The derivation of the theoretical model is detailed in **Calculation 1**. **Equation 1**, **Equation 2** and **Equation 3** were used for the linear, exponential and theoretical models respectively. The implementations shown in **Function 1**, **Function 2** and **Function 3** were used for curve_fit. The exponential and theoretical model regressions were performed on the raw data set and the linear regression was performed using the linearized data.

All data linearization was done using a natural logarithm on the corresponding y-axis. This was used for linear modelling in addition to the linearized plotting in **Figure 2** of the data, exponential and theoretical models. To plot the linear model on **Figure 1**, the output values of the linear model regression were delinearized by taking the exponential of them (base e).

Uncertainty Calculations

Uncertainty in count measurements were all calculated using **Equation 8**. This was done programmatically for all measured values using the python implementation **Function 5**. Sample calculations for the first reading are shown in **Calculation 2**.

Uncertainty was propagated for the linearization by using the logarithmic error propagation shown in **Equation 6**. This again was done programmatically for all values using the python implementation **Function 4**. Sample calculations for the first reading are shown in **Calculation 3**

Experiment 2

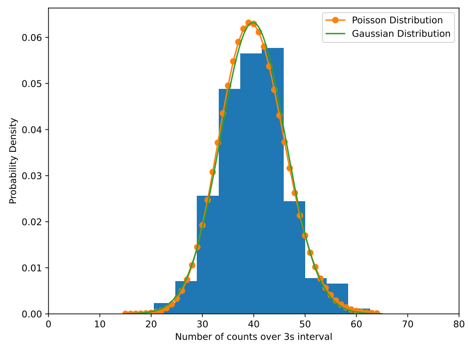

Figure 3: Probability density for various ranges of counts measured over 3s intervals. Data is from the fiesta plate sample measurements. Includes both Poisson and Gaussian distributions.

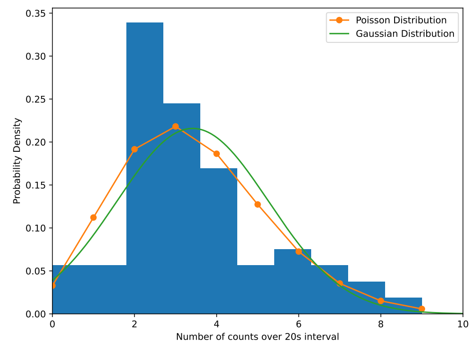

Figure 4: Probability density for various ranges of counts measured over 20s intervals. Data is from the background radiation sample measurements. Includes both Poisson and Gaussian distributions.

Histograms

Histogram plots in **Figure 3** and **Figure 4** were done using the hst function from the matplotlib.pyplot package with the density set to true, generating a probability density histogram rather than a count histogram. All binning was done automatically by the hst function. The plot in **Figure 3** shows the count values after the mean background radiation had been subtracted.

Gaussian and Poisson Distributions

For the Poisson distributions, the poisson.pmf function from scipy.stats was used. This function is an implementation of the Poisson probability mass function (**Equation 9**). For both the background and fiesta plate datasets, the provided μ value was the mean radiation that was detected over the course of the respective experiment.

For the Gaussian distributions, the norm.pdf function from scipy.stats was used. This function uses the probability density function (**Equation 10**) to generate a normal distribution. The scale and location for each distribution was set based on the average count over the respective experiment (μ). One standard deviation (σ) was set to $\sqrt{\mu}$ and the location of the distribution was set to μ.

3 Analysis

Experiment 1

The chi-squared values for each graph were calculated programmatically using **Function 6** (implementing **Equation 7**). Details of how the half life and initial intensity were calculated are shown in **Calculation 4**. The calculated half life and initial intensity in addition to the chi-squared value for the linear and exponential are as follows.

Linear Regression: The half-life was determined to be $145 \pm 6s$ and the initial intensity value (I_0) was determined to be $760 \pm 70\frac{J}{m^2s}$. The chi-squared value was calculated as $\chi^2 = 1.30$.

Exponential Regression: The half life was determined to be $148 \pm 3s$ and the initial intensity value (I_0) was determined to be $717 \pm 8\frac{J}{m^2s}$. The chi-squared value was calculated $\chi^2 = 0.98$.

The exponential model gave a value closer to the theoretical half life of 156 seconds, however, the theoretical half life does not fall in the uncertainty range of either model.
In **Figure 1** and **Figure 2**, both the linear and exponential curves visually fit the experimental data quite well, with the exponential regression method tending closer to the theoretical curve. This can be clearly seen in **Figure 2**, where the exponential model is visually closer to the theoretical curve.
Analyzing the chi-squared values for each graph, the nonlinear regression's value of 0.98 is much closer to the ideal value of 1 than the linear regression's value of 1.30. Although the value determined from the linear model deviates slightly farther, it is still relatively close to the accepted value. Ultimately, the reduced chi-squared values indicate that both models are good fits. However, nonlinear regression provides values that more closely approximate the experimental data.

Experiment 2

Examining the fiesta plate data in **Figure 3**, the Poisson distribution is a very close approximation of the Gaussian distribution. There was a larger visual discrepancy between the two distributions in the background data in **Figure 4**. The Poisson distribution in **Figure 4** is notably shifted left of the Gaussian distribution. Due to the discrete, non-negative nature of Poisson distributions, as $\mu \to 0$, they will become less and less symmetrical and will fall off much more steeply on the left. This is not reflected in Gaussian distributions which have the possibility of having positive probabilities for negative numbers. The Poisson distribution in **Figure 4** is clearly not symmetrical and has a noticeably steeper slope on the left side. This indicates why **Figure 3** with its much higher μ value is a much better approximation of a Gaussian distribution.

Visually, the experimental data in **Figure 3** appears to be a much better approximation of both the Poisson and Gaussian distributions. The experimental data in **Figure 4** seems to be a better approximation of the Poisson distribution which makes sense due to the positive discrete data set provided by a Geiger counter and the data's proximity to counts of 0.

4 Discussion

Experiment 1

Although the experimental half-lives were slightly less than the expected value, this was likely due to the background radiation which had to be subtracted from the collected data. The experiment ultimately verifies that the intensity of radiation decays exponentially and agrees that the half-life of Barium-137 is approximately 2.6 minutes. If the mean background radiation could be calculated with a larger sample size, a more accurate background radiation level could likely be determined. Modifications to a future experiment could include a longer period of background radiation measurements with a smaller interval to get more data points and by extension a more accurate approximation.

Experiment 2

More count data points would likely create a more accurate model of the radioactive emission for both the background and the fiesta plate. This could be achieved by measuring both for a longer period of time.

To get a Gaussian and Poisson distribution that are more similar, altering the measurement method to get a higher μ value would be the solution. This is due to the fact that Poisson distributions tend towards Gaussian normal distributions as $\mu \to \infty$. This could be achieved experimentally by extending the length of the intervals to get a larger number for each count value. This would likely make a significant difference for the background data as it is so close to 0.

Experiment 1 and experiment 2 can both be improved by altering the intervals for the background measurement. Improvements would come from a background measurement interval length decrease in experiment 1 and an increase in experiment 2. Therefore, for a future experiment, it would be advantageous to record the background radiation twice over different intervals. This would give two datasets that provide more useful information for each experiments' analysis.

5 Conclusion

The results of this lab for both experiments 1 and 2 were generally quite close to their theoretical values. However, the experimental values and models both deviated away from expected values. Thus, it is evident that a factor, such as the background radiation, slightly skewed the experimental results.. This is likely an issue with the background radiation measurement. Larger sample sizes for background radiation and the measurement interval changes discussed in the **Discussion** section would reduce this error.

6 Appendix

Equations

$$f(x) = ax + b$$

Equation 1: Linear Model

$$f(x) = be^{ax}$$

Equation 2: Exponential Model

$$I(t) = I_0 e^{-\frac{t \ln 2}{156}}$$

Equation 3: Theoretical Model

$$I(t) = I_0 e^{-\frac{t}{\tau}}$$

Equation 4: Mean isotope lifetime equation

$$\tau = \frac{t_{1/2}}{\ln 2}$$

Equation 5: Mean isotope lifetime to half life conversion

$$u\left(\ln(x_i)\right) = \pm \left| \frac{u(x_i)}{x_i} \right|$$

Equation 6: Error Propagation for logarithms

$$\chi^2 = \sum_{i=1}^{N} \left(\frac{y_i - y(x_i)}{u(y_i)} \right)$$

Equation 7: Chi-Squared Metric

$$u(N_i) = \pm \sqrt{N_{total,i} + \bar{N}_b}$$

Equation 8: Geiger Counter Uncertainty

$$P_\mu(n) = e^{-\mu} \frac{\mu^n}{\Gamma(n+1)}$$

Equation 9: Poisson mass distribution function

$$f(x) = \frac{e^{-x^2/2}}{\sqrt{2\pi}}$$

Equation 10: Gaussian probability density function

Python Functions

Models

```
def linear_model(values, a, b) -> any:
     return a * values + b
```

Function 1: Linear Model (implements Equation 1)

```
def exponential_model(values, a, b) -> any:
     return b * np.exp(a * values)
```

Function 2: Exponential Model (implements Equation 2)

```
def theoretical_model(values, b) -> any:
    return b * np.exp((-1 / 156 * np.log(2)) * values)
```

Function 3: Theoretical Model (implements Equation 3)

Uncertainty

```
def logarithmic_error_propagation(value: any, uncertainty: any) -> float:
    """Return the propogated error for the logarithm of a value"""
    return abs(uncertainty / value)
```

Function 4: Logarithmic Error Propagation (implements Equation 6)

```
def calculate_uncertainty(count, mean_background) -> any:
    """Return the uncertainty of the sample.
    """
    return np.sqrt(count + mean_background)
```

Function 5: Function used to calculate count uncertainty values (implements Equation 8)

Data Analysis

```
def characterize(y: any, func: any, u: any) -> float:
    """Return the reduced chi-squared metric to determine how well a model
    function fits a given set of data using the measured data <y>, the
    prediction with the model <func> and the uncertainty on each measurement's
    dependent data <u>.
    """
    value = 0

    for i in range(np.size(y)):
        value += ((y[i] - func[i]) ** 2) / (u[i] ** 2)
        i += 1

    return value / (np.size(y) - 2)
```

Function 6: Function used to calculate chi-squared metric (implements equation 7)

```
def count_rate(events, sample_time) -> tuple:
    """Return the count rate and its uncertainty.
    """
    return events / sample_time, np.sqrt(events) / sample_time
```

Function 7: Function used to calculate count-rate for experimental data

Sample Calculations

The theoretical model was derived by first combining of **Equation 4** and **Equation 5**:

$$I(t) = I_0 e^{-\frac{t}{\tau}} \iff I(t) = I_0 e^{-\frac{t}{\frac{t_{1/2}}{\ln 2}}} \iff I(t) = I_0 e^{-\frac{t \ln 2}{t_{1/2}}}$$

The theoretical value for the half-life of Barium ($t_{\frac{1}{2}} = 156s$) was included in the equation:

$$I(t) = I_0 e^{-\frac{t \ln 2}{156}}$$

Calculation 1: Deriving Theoretical Model

All Geiger counter uncertainty calculations are based off of **Equation 8**. The mean of the background radiation count measured in the lab over each 20 second interval was $\bar{N}_b \approx 3.42$, therefore:

$$u(N_i) = \pm\sqrt{N_{total,i} + 3.42}$$

The first count value N_1 measured in experiment 1 was $N_1 = 666$. Therefore:

$$u(N_1) = \pm\sqrt{666 + 3.42} = \pm\sqrt{669.42} \approx \pm 25.87$$

Uncertainty for all values was calculated in this manner programmatically using **Function 5** which is an implementation of **Equation 8**.

Calculation 2: Sample Geiger Counter uncertainty calculation

The error values for the linearized plot were calculated using **Equation 6**. The first measured count value with background subtracted was $N_1' = 662.6$ and the uncertainty of the first measurement $u(N_1') \approx 25.87$ as shown in **Calculation 2**. Therefore, by **Equation 6**:

$$u(\ln(N_1')) = \pm\left|\frac{u(N_1')}{N_1'}\right| = \pm\left|\frac{25.87}{662.6}\right| \approx \pm 0.039$$

Calculation 3: Sample logarithmic error propagation

Raw Data

Time Interval (s)	Total Measured Count
0-20	3
20-40	5
40-60	4
60-80	2
80-100	3
100-120	6
120-140	4
140-160	2
160-180	8
180-200	4
200-220	2
220-240	2
240-260	3
260-280	2
280-300	0
300-320	8
320-340	2
340-360	7
360-380	5
380-400	3
400-420	2
420-440	2
440-460	4
460-480	3
480-500	2
500-520	2
520-540	3
540-560	3
560-580	6
580-600	3

Time Interval (s)	Total Measured Count
600-620	2
620-640	2
640-660	0
660-680	3
680-700	4
700-720	6
720-740	4
740-760	4
760-780	3
780-800	7
800-820	3
820-840	5
840-860	2
860-880	2
880-900	3
900-920	2
920-940	6
940-960	4
960-980	2
980-1000	9
1000-1020	0
1020-1040	2
1040-1060	6
1060-1080	3
1080-1100	2
1100-1120	4
1120-1140	1
1140-1160	7
1160-1180	1
1180-1200	1

Table 1: Raw data from the background radiation measurement, time intervals and measured counts are shown.

Time Interval (s)	Total Measured Count	Count without background
0-20	666	663 ± 30
20-40	628	625 ± 30
40-60	526	523 ± 20
60-80	466	463 ± 20
80-100	477	474 ± 20
100-120	382	379 ± 20
120-140	393	390 ± 20
140-160	328	325 ± 20
160-180	314	311 ± 20
180-200	266	263 ± 20
200-220	270	267 ± 20
220-240	216	213 ± 10
240-260	238	235 ± 20
260-280	181	178 ± 10
280-300	189	186 ± 10
300-320	154	151 ± 10
320-340	161	158 ± 10
340-360	142	139 ± 10
360-380	131	128 ± 10
380-400	119	116 ± 10
400-420	109	106 ± 10
420-440	96	93 ± 10
440-460	88	85 ± 10
460-480	72	69 ± 9
480-500	84	81 ± 9
500-520	63	60 ± 8
520-540	59	56 ± 8
540-560	47	44 ± 7
560-580	62	59 ± 8
580-600	54	51 ± 8
600-620	32	29 ± 6
620-640	32	29 ± 6
640-660	39	36 ± 7
660-680	44	41 ± 7
680-700	30	27 ± 6
700-720	38	35 ± 6
720-740	33	30 ± 6
740-760	24	21 ± 5
760-780	19	16 ± 5
780-800	24	21 ± 5
800-820	28	25 ± 6
820-840	22	19 ± 5
840-860	8	5 ± 3
860-880	18	15 ± 5
880-900	17	14 ± 5
900-920	11	8 ± 4
920-940	12	9 ± 4
940-960	15	12 ± 4
960-980	13	10 ± 4
980-1000	16	13 ± 4
1000-1020	8	5 ± 3
1020-1040	6	3 ± 3
1040-1060	3	0 ± 3
1060-1080	8	5 ± 3
1080-1100	6	3 ± 3
1100-1120	13	10 ± 4
1120-1140	8	5 ± 3
1140-1160	4	1 ± 3
1160-1180	5	2 ± 3
1180-1200	6	3 ± 3

Table 2: Raw data from experiment 1 showing time intervals, total measured counts and rounded counts with background subtracted.

Time Interval (s)	Total Measured Count	Count without background
0-3	39	36 ± 7
3-6	39	36 ± 7
6-9	42	39 ± 7
9-12	33	30 ± 6
12-15	49	46 ± 7
15-18	32	29 ± 6
18-21	31	28 ± 6
21-24	54	51 ± 8
24-27	60	57 ± 8
27-30	40	37 ± 7
30-33	42	39 ± 7
33-36	45	42 ± 7
36-39	61	58 ± 8
39-42	45	42 ± 7
42-45	42	39 ± 7
45-48	49	46 ± 7
48-51	44	41 ± 7
51-54	41	38 ± 7
54-57	53	50 ± 8
57-60	46	43 ± 7
60-63	39	36 ± 7
63-66	35	32 ± 6
66-69	43	40 ± 7
69-72	41	38 ± 7
72-75	49	46 ± 7
75-78	50	47 ± 7
78-81	59	56 ± 8
81-84	47	44 ± 7
84-87	41	38 ± 7
87-90	37	34 ± 6
90-93	38	35 ± 6
93-96	53	50 ± 8
96-99	38	35 ± 6
99-102	37	34 ± 6
102-105	52	49 ± 7
105-108	46	43 ± 7
108-111	41	38 ± 7
111-114	32	29 ± 6
114-117	35	32 ± 6
117-120	39	36 ± 7

Time Interval (s)	Total Measured Count	Count without background
120-123	39	36 ± 7
123-126	39	36 ± 7
126-129	34	31 ± 6
129-132	46	43 ± 7
132-135	42	39 ± 7
135-138	39	36 ± 7
138-141	52	49 ± 7
141-144	51	48 ± 7
144-147	59	56 ± 8
147-150	42	39 ± 7
150-153	52	49 ± 7
153-156	36	33 ± 6
156-159	48	45 ± 7
159-162	47	44 ± 7
162-165	44	41 ± 7
165-168	41	38 ± 7
168-171	37	34 ± 6
171-174	53	50 ± 8
174-177	45	42 ± 7
177-180	52	49 ± 7
180-183	44	41 ± 7
183-186	42	39 ± 7
186-189	53	50 ± 8
189-192	47	44 ± 7
192-195	51	48 ± 7
195-198	45	42 ± 7
198-201	41	38 ± 7
201-204	46	43 ± 7
204-207	39	36 ± 7
207-210	54	51 ± 8
210-213	51	48 ± 7
213-216	45	42 ± 7
216-219	35	32 ± 6
219-222	44	41 ± 7
222-225	46	43 ± 7
225-228	40	37 ± 7
228-231	44	41 ± 7
231-234	47	44 ± 7
234-237	37	34 ± 6
237-240	36	33 ± 6

Time Interval (s)	Total Measured Count	Count without background
240-243	40	37 ± 7
243-246	32	29 ± 6
246-249	51	48 ± 7
249-252	40	37 ± 7
252-255	33	30 ± 6
255-258	45	42 ± 7
258-261	37	34 ± 6
261-264	58	55 ± 8
264-267	50	47 ± 7
267-270	37	34 ± 6
270-273	38	35 ± 6
273-276	48	45 ± 7
276-279	49	46 ± 7
279-282	39	36 ± 7
282-285	40	37 ± 7
285-288	45	42 ± 7
288-291	43	40 ± 7
291-294	55	52 ± 8
294-297	37	34 ± 6
297-300	36	33 ± 6
300-303	40	37 ± 7
303-306	40	37 ± 7
306-309	38	35 ± 6
309-312	43	40 ± 7
312-315	51	48 ± 7
315-318	49	46 ± 7
318-321	58	55 ± 8
321-324	36	33 ± 6
324-327	47	44 ± 7
327-330	41	38 ± 7
330-333	43	40 ± 7
333-336	48	45 ± 7
336-339	42	39 ± 7
339-342	50	47 ± 7
342-345	53	50 ± 8
345-348	49	46 ± 7
348-351	51	48 ± 7
351-354	41	38 ± 7
354-357	45	42 ± 7
357-360	37	34 ± 6

Time Interval (s)	Total Measured Count	Count without background
360-363	30	27 ± 6
363-366	40	37 ± 7
366-369	44	41 ± 7
369-372	47	44 ± 7
372-375	48	45 ± 7
375-378	41	38 ± 7
378-381	34	31 ± 6
381-384	41	38 ± 7
384-387	41	38 ± 7
387-390	43	40 ± 7
390-393	47	44 ± 7
393-396	45	42 ± 7
396-399	39	36 ± 7
399-402	47	44 ± 7
402-405	45	42 ± 7
405-408	27	24 ± 6
408-411	50	47 ± 7
411-414	47	44 ± 7
414-417	44	41 ± 7
417-420	47	44 ± 7
420-423	46	43 ± 7
423-426	48	45 ± 7
426-429	33	30 ± 6
429-432	34	31 ± 6
432-435	42	39 ± 7
435-438	43	40 ± 7
438-441	39	36 ± 7
441-444	46	43 ± 7
444-447	38	35 ± 6
447-450	40	37 ± 7
450-453	36	33 ± 6
453-456	49	46 ± 7
456-459	50	47 ± 7
459-462	40	37 ± 7
462-465	50	47 ± 7
465-468	53	50 ± 8
468-471	54	51 ± 8
471-474	37	34 ± 6
474-477	41	38 ± 7
477-480	44	41 ± 7

Time Interval (s)	Total Measured Count	Count without background	Time Interval (s)	Total Measured Count	Count without background
480-483	58	55 ± 8	600-603	32	29 ± 6
483-486	42	39 ± 7	603-606	48	45 ± 7
486-489	51	48 ± 7	606-609	47	44 ± 7
489-492	41	38 ± 7	609-612	42	39 ± 7
492-495	50	47 ± 7	612-615	24	21 ± 5
495-498	45	42 ± 7	615-618	55	52 ± 8
498-501	41	38 ± 7	618-621	54	51 ± 8
501-504	42	39 ± 7	621-624	43	40 ± 7
504-507	48	45 ± 7	624-627	48	45 ± 7
507-510	42	39 ± 7	627-630	43	40 ± 7
510-513	39	36 ± 7	630-633	59	56 ± 8
513-516	50	47 ± 7	633-636	33	30 ± 6
516-519	47	44 ± 7	636-639	41	38 ± 7
519-522	49	46 ± 7	639-642	45	42 ± 7
522-525	47	44 ± 7	642-645	54	51 ± 8
525-528	33	30 ± 6	645-648	36	33 ± 6
528-531	37	34 ± 6	648-651	40	37 ± 7
531-534	52	49 ± 7	651-654	41	38 ± 7
534-537	46	43 ± 7	654-657	54	51 ± 8
537-540	38	35 ± 6	657-660	42	39 ± 7
540-543	42	39 ± 7	660-663	42	39 ± 7
543-546	37	34 ± 6	663-666	46	43 ± 7
546-549	30	27 ± 6	666-669	43	40 ± 7
549-552	48	45 ± 7	669-672	30	27 ± 6
552-555	47	44 ± 7	672-675	46	43 ± 7
555-558	38	35 ± 6	675-678	47	44 ± 7
558-561	41	38 ± 7	678-681	39	36 ± 7
561-564	34	31 ± 6	681-684	55	52 ± 8
564-567	35	32 ± 6	684-687	45	42 ± 7
567-570	36	33 ± 6	687-690	47	44 ± 7
570-573	39	36 ± 7	690-693	46	43 ± 7
573-576	36	33 ± 6	693-696	50	47 ± 7
576-579	43	40 ± 7	696-699	40	37 ± 7
579-582	55	52 ± 8	699-702	44	41 ± 7
582-585	43	40 ± 7	702-705	66	63 ± 8
585-588	45	42 ± 7	705-708	39	36 ± 7
588-591	32	29 ± 6	708-711	43	40 ± 7
591-594	51	48 ± 7	711-714	42	39 ± 7
594-597	45	42 ± 7	714-717	55	52 ± 8
597-600	57	54 ± 8	717-720	41	38 ± 7

Time Interval (s)	Total Measured Count	Count without background
720-723	49	46 ± 7
723-726	58	55 ± 8
726-729	45	42 ± 7
729-732	47	44 ± 7
732-735	42	39 ± 7
735-738	61	58 ± 8
738-741	44	41 ± 7
741-744	35	32 ± 6
744-747	39	36 ± 7
747-750	44	41 ± 7
750-753	35	32 ± 6
753-756	41	38 ± 7
756-759	53	50 ± 8
759-762	47	44 ± 7
762-765	63	60 ± 8
765-768	35	32 ± 6
768-771	47	44 ± 7
771-774	36	33 ± 6
774-777	37	34 ± 6
777-780	33	30 ± 6
780-783	43	40 ± 7
783-786	33	30 ± 6
786-789	44	41 ± 7
789-792	44	41 ± 7
792-795	39	36 ± 7
795-798	41	38 ± 7
798-801	48	45 ± 7
801-804	34	31 ± 6
804-807	36	33 ± 6
807-810	40	37 ± 7
810-813	41	38 ± 7
813-816	38	35 ± 6
816-819	43	40 ± 7
819-822	46	43 ± 7
822-825	39	36 ± 7
825-828	37	34 ± 6
828-831	44	41 ± 7
831-834	47	44 ± 7
834-837	46	43 ± 7
837-840	42	39 ± 7

Time Interval (s)	Total Measured Count	Count without background
840-843	36	33 ± 6
843-846	34	31 ± 6
846-849	50	47 ± 7
849-852	53	50 ± 8
852-855	24	21 ± 5
855-858	48	45 ± 7
858-861	49	46 ± 7
861-864	45	42 ± 7
864-867	50	47 ± 7
867-870	27	24 ± 6
870-873	33	30 ± 6
873-876	47	44 ± 7
876-879	37	34 ± 6
879-882	41	38 ± 7
882-885	45	42 ± 7
885-888	41	38 ± 7
888-891	49	46 ± 7
891-894	31	28 ± 6
894-897	41	38 ± 7
897-900	51	48 ± 7
900-903	36	33 ± 6
903-906	43	40 ± 7
906-909	48	45 ± 7
909-912	43	40 ± 7
912-915	46	43 ± 7
915-918	40	37 ± 7
918-921	48	45 ± 7
921-924	37	34 ± 6
924-927	40	37 ± 7
927-930	46	43 ± 7
930-933	44	41 ± 7
933-936	39	36 ± 7
936-939	45	42 ± 7
939-942	39	36 ± 7
942-945	40	37 ± 7
945-948	40	37 ± 7
948-951	39	36 ± 7
951-954	44	41 ± 7
954-957	45	42 ± 7
957-960	37	34 ± 6

Time Interval (s)	Total Measured Count	Count without background
960-963	44	41 ± 7
963-966	40	37 ± 7
966-969	41	38 ± 7
969-972	54	51 ± 8
972-975	37	34 ± 6
975-978	35	32 ± 6
978-981	50	47 ± 7
981-984	39	36 ± 7
984-987	38	35 ± 6
987-990	38	35 ± 6
990-993	53	50 ± 8
993-996	43	40 ± 7
996-999	49	46 ± 7
999-1002	33	30 ± 6
1002-1005	39	36 ± 7
1005-1008	40	37 ± 7
1008-1011	49	46 ± 7
1011-1014	45	42 ± 7
1014-1017	40	37 ± 7
1017-1020	35	32 ± 6
1020-1023	46	43 ± 7
1023-1026	44	41 ± 7
1026-1029	40	37 ± 7
1029-1032	50	47 ± 7
1032-1035	42	39 ± 7
1035-1038	35	32 ± 6
1038-1041	32	29 ± 6
1041-1044	51	48 ± 7
1044-1047	58	55 ± 8
1047-1050	46	43 ± 7
1050-1053	47	44 ± 7
1053-1056	47	44 ± 7
1056-1059	42	39 ± 7
1059-1062	44	41 ± 7
1062-1065	43	40 ± 7
1065-1068	39	36 ± 7
1068-1071	42	39 ± 7
1071-1074	45	42 ± 7
1074-1077	36	33 ± 6
1077-1080	40	37 ± 7
1080-1083	38	35 ± 6
1083-1086	42	39 ± 7
1086-1089	35	32 ± 6
1089-1092	38	35 ± 6
1092-1095	39	36 ± 7
1095-1098	49	46 ± 7
1098-1101	51	48 ± 7
1101-1104	44	41 ± 7
1104-1107	38	35 ± 6
1107-1110	39	36 ± 7
1110-1113	44	41 ± 7
1113-1116	43	40 ± 7
1116-1119	31	28 ± 6
1119-1122	52	49 ± 7
1122-1125	48	45 ± 7
1125-1128	43	40 ± 7
1128-1131	35	32 ± 6
1131-1134	51	48 ± 7
1134-1137	44	41 ± 7
1137-1140	44	41 ± 7
1140-1143	46	43 ± 7
1143-1146	38	35 ± 6
1146-1149	48	45 ± 7
1149-1152	46	43 ± 7
1152-1155	42	39 ± 7
1155-1158	52	49 ± 7
1158-1161	40	37 ± 7
1161-1164	46	43 ± 7
1164-1167	41	38 ± 7
1167-1170	44	41 ± 7
1170-1173	40	37 ± 7
1173-1176	45	42 ± 7
1176-1179	44	41 ± 7
1179-1182	33	30 ± 6
1182-1185	40	37 ± 7
1185-1188	42	39 ± 7
1188-1191	45	42 ± 7
1191-1194	33	30 ± 6
1194-1197	34	31 ± 6
1197-1200	48	45 ± 7

Table 3: Raw data from experiment 2 showing time intervals, total measured counts and rounded counts with background subtracted.