

Versuch 252: Aktivierung von Indium und Silber

```
In[262]= Needs["ErrorBarPlots`"]
```

Zerfall der Silberisotope

Untergrundbestimmung

```
In[263]= dataAg,bg = Import[  
    "/Users/jannis/Dropbox/uniself/AP2/2.2/252 Aktivierung/UntergrundAgJJ.dat"]
```

```
Out[263]= {{1, 3}, {2, 7}, {3, 4}, {4, 5}, {5, 4}, {6, 2}, {7, 6}, {8, 1}, {9, 1}, {10, 2},  
    {11, 3}, {12, 3}, {13, 3}, {14, 2}, {15, 4}, {16, 3}, {17, 1}, {18, 2}, {19, 1},  
    {20, 2}, {21, 2}, {22, 2}, {23, 8}, {24, 9}, {25, 2}, {26, 3}, {27, 0}, {28, 5},  
    {29, 0}, {30, 3}, {31, 2}, {32, 5}, {33, 1}, {34, 4}, {35, 2}, {36, 5}, {37, 6},  
    {38, 3}, {39, 2}, {40, 1}, {41, 3}, {42, 5}, {43, 7}, {44, 4}, {45, 4},  
    {46, 4}, {47, 5}, {48, 3}, {49, 3}, {50, 5}, {51, 1}, {52, 4}, {53, 6},  
    {54, 2}, {55, 1}, {56, 3}, {57, 6}, {58, 3}, {59, 4}, {60, 1}, {61, 4}}
```

```
In[264]= ttor,Ag = Quantity[10, "Seconds"]
```

```
Out[264]= 10 s
```

```
In[265]= ttor,In = Quantity[120, "Seconds"]
```

```
Out[265]= 120 s
```

```
In[266]= {A0, ΔA0} = UnitConvert[  
    ({Mean[d], StandardDeviation[d]} / ttor,Ag) /. {d → dataAg,bg[[All, 2]]} // N,  
    "Becquerels"]
```

```
Out[266]= {0.331148 Bq, 0.194543 Bq}
```

Bestimmung der Zerfallskonstanten

Datenimport

```
In[267]= dataAg,1 = Import[  
    "/Users/jannis/Dropbox/uniself/AP2/2.2/252 Aktivierung/Messung1Ag.dat"][[;;  
    40, 2]]
```

```
Out[267]= {74, 71, 64, 47, 44, 32, 31, 20, 18, 17, 17, 17, 15, 16, 11, 24, 14, 10,  
    10, 9, 19, 12, 15, 11, 17, 10, 9, 8, 6, 5, 11, 1, 11, 7, 8, 5, 5, 4, 6, 6}
```

```
In[268]:= dataAg,2 = Import[
  "/Users/jannis/Dropbox/uniself/AP2/2.2/252 Aktivierung/Messung2Ag.dat" ][[ ;;
  40, 2]]
```

```
Out[268]= {81, 69, 41, 50, 40, 30, 35, 23, 9, 26, 14, 18, 13, 12, 12, 11, 16,
  15, 5, 12, 18, 8, 7, 7, 9, 8, 9, 7, 7, 12, 8, 5, 3, 5, 7, 7, 3, 5, 9, 8}
```

```
In[269]:= dataAg,3 = Import[
  "/Users/jannis/Dropbox/uniself/AP2/2.2/252 Aktivierung/Messung3Ag.dat" ][[ ;;
  40, 2]]
```

```
Out[269]= {70, 51, 39, 40, 28, 29, 23, 17, 24, 16, 13, 16, 15, 19, 17, 6, 8,
  9, 10, 12, 10, 9, 12, 12, 5, 6, 6, 6, 8, 6, 4, 7, 4, 5, 10, 5, 8, 5, 6, 9}
```

```
In[270]:= dataAg,4 = Import[
  "/Users/jannis/Dropbox/uniself/AP2/2.2/252 Aktivierung/Messung4Ag.dat" ][[ ;;
  40, 2]]
```

```
Out[270]= {78, 53, 56, 38, 26, 26, 25, 27, 22, 18, 7, 13, 15, 19, 14, 8, 9, 9,
  6, 10, 14, 7, 4, 14, 13, 9, 7, 9, 7, 3, 12, 3, 7, 7, 6, 8, 3, 10, 1, 4}
```

Aufbereitung der Daten

```
In[271]:= {dataAg, errorsAg} = {d, N /@ Sqrt[d]} /. {d → Total[Array[dataAg, # &, 4]]}
```

```
Out[271]= {{303, 244, 200, 175, 138, 117, 114, 87, 73, 77, 51, 64, 58, 66, 54, 49, 47, 43, 31, 43,
  61, 36, 38, 44, 44, 33, 31, 30, 28, 26, 35, 16, 25, 24, 31, 25, 19, 24, 22, 27},
  {17.4069, 15.6205, 14.1421, 13.2288, 11.7473, 10.8167, 10.6771,
  9.32738, 8.544, 8.77496, 7.14143, 8., 7.61577, 8.12404, 7.34847, 7.,
  6.85565, 6.55744, 5.56776, 6.55744, 7.81025, 6., 6.16441, 6.63325,
  6.63325, 5.74456, 5.56776, 5.47723, 5.2915, 5.09902, 5.91608,
  4., 5., 4.89898, 5.56776, 5., 4.3589, 4.89898, 4.69042, 5.19615}}
```

```
In[272]:= timesAg = Array[Quantity[10 * # - 5, "Seconds"] &, Length[dataAg]]
```

```
Out[272]= {5 s, 15 s, 25 s, 35 s, 45 s, 55 s, 65 s, 75 s, 85 s, 95 s, 105 s, 115 s, 125 s, 135 s, 145 s,
  155 s, 165 s, 175 s, 185 s, 195 s, 205 s, 215 s, 225 s, 235 s, 245 s, 255 s, 265 s, 275 s,
  285 s, 295 s, 305 s, 315 s, 325 s, 335 s, 345 s, 355 s, 365 s, 375 s, 385 s, 395 s}
```

```
In[273]:= valuesAg = Transpose[{timesAg // QuantityMagnitude, dataAg}];
```

Plot und Fit

```
In[274]:= {aAg,0, ΔaAg,0} = ttor,Ag * {A0, ΔA0}
```

```
Out[274]= {3.31148, 1.94543}
```

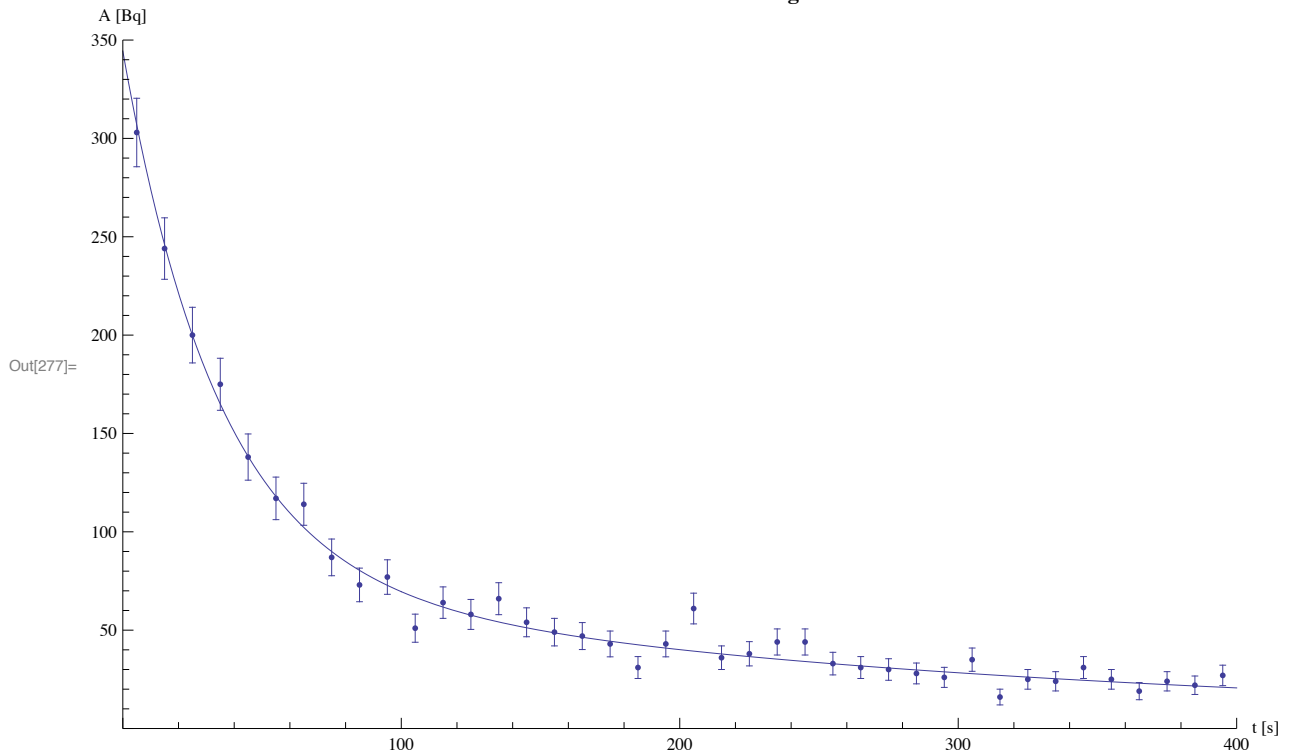
```
In[275]:= plotAg = ErrorListPlot[Table[{valuesAg[[i]], ErrorBar[errorsAg[[i]]]},
  {i, 1, Length[dataAg]}], PlotRange → {{0, 400}, {0, 350}},
  PlotLabel → Style["Zerfall von Silber mit Untergrund", Bold],
  AxesLabel → {"t [s]", "A [Bq]"}, ImageSize → Full, AxesOrigin → {0, 0};
```

```
In[276]:= fitAg,0 = NonlinearModelFit[valuesAg,
QuantityMagnitude[aAg,0] + A1 Exp[- $\frac{x}{t_1}$ ] + A2 Exp[- $\frac{x}{t_2}$ ], {A1, A2, t1, t2},
{x}, Weights ->  $\frac{1}{\text{errors}_{Ag}^2}$ , VarianceEstimatorFunction -> (1 &)]
```

```
Out[276]= FittedModel[3.31148 + 266.274 e<<1> + 74.8183 e-<<22>>x]
```

```
In[277]:= Show[plotAg, Plot[fitAg,0[x], {x, 0, 100}], Plot[fitAg,0[x], {x, 100, 400}]]
```

Zerfall von Silber mit Untergrund



```
In[319]:= fitAg,0["ParameterTable"]
```

	Estimate	Standard Error	t-Statistic	P-Value
A ₁	74.8183	11.8842	6.29559	2.80369 × 10 ⁻⁷
A ₂	266.274	17.7107	15.0346	4.30419 × 10 ⁻¹⁷
t ₁	273.536	43.9094	6.22956	3.43308 × 10 ⁻⁷
t ₂	34.2418	4.17183	8.20787	9.16716 × 10 ⁻¹⁰

```
In[278]:= ( $\chi^2$ )Ag = Total[
Table[ $\frac{(\text{values}_{Ag}[[i, 2]] - \text{fit}_{Ag,0}[\text{values}_{Ag}[[i, 1]])^2}{\text{errors}_{Ag}[[i]]^2}$ , {i, 1, Length[valuesAg]}]]]
```

```
Out[278]= 39.7316
```

```
In[321]:= Length[valuesAg]
```

```
Out[321]= 40
```

```
In[324]:= 1 - CDF[ChiSquareDistribution[Length[valuesAG] - 5]] [(χ2)AG]
```

```
Out[324]:= 0.26736
```

Fehlerfortpflanzung des Fehlers auf den Hintergrund

```
In[280]:= fitAG,-σ = NonlinearModelFit[valuesAG,
  QuantityMagnitude[aAG,0 - ΔaAG,0] + A1 Exp[- $\frac{x}{t_1}$ ] + A2 Exp[- $\frac{x}{t_2}$ ], {A1, A2, t1, t2},
  {x}, Weights →  $\frac{1}{\text{errors}_{AG}^2}$ , VarianceEstimatorFunction → (1 &)]
```

```
Out[280]:= FittedModel[1.36605 + 267.57 e<<1>> + 75.1882 e-<<21>>x]
```

```
In[281]:= fitAG,+σ = NonlinearModelFit[valuesAG,
  QuantityMagnitude[aAG,0 + ΔaAG,0] + A1 Exp[- $\frac{x}{t_1}$ ] + A2 Exp[- $\frac{x}{t_2}$ ], {A1, A2, t1, t2},
  {x}, Weights →  $\frac{1}{\text{errors}_{AG}^2}$ , VarianceEstimatorFunction → (1 &)]
```

```
Out[281]:= FittedModel[5.25691 + 264.73 e<<1>> + 74.7225 e-<<21>>x]
```

```
In[282]:= {{tAG,1,0, ΔtAG,1,0}, {tAG,2,0, ΔtAG,2,0}} =
  fitAG,0["ParameterTableEntries"][[3 ;; 4, 1 ;; 2]]
```

```
Out[282]:= {{273.536, 43.9094}, {34.2418, 4.17183}}
```

```
In[283]:= {{tAG,1,-σ, ΔtAG,1,-σ}, {tAG,2,-σ, ΔtAG,2,-σ}} =
  fitAG,-σ["ParameterTableEntries"][[3 ;; 4, 1 ;; 2]]
```

```
Out[283]:= {{292.581, 47.1027}, {34.4837, 4.10328}}
```

```
In[284]:= {{tAG,1,+σ, ΔtAG,1,+σ}, {tAG,2,+σ, ΔtAG,2,+σ}} =
  fitAG,+σ["ParameterTableEntries"][[3 ;; 4, 1 ;; 2]]
```

```
Out[284]:= {{254.62, 40.7679}, {33.9669, 4.25312}}
```

```
In[285]:= ΔtAG,1,fit = Mean[{Abs[tAG,1,0 - tAG,1,-σ], Abs[tAG,1,0 - tAG,1,+σ]}]
```

```
Out[285]:= 18.9808
```

```
In[286]:= ΔtAG,2,fit = Mean[{Abs[tAG,2,0 - tAG,2,-σ], Abs[tAG,2,0 - tAG,2,+σ]}]
```

```
Out[286]:= 0.258376
```

Resultate

```
In[311]:= {tAG,1, ΔtAG,1} = Quantity[{tAG,1,0,  $\sqrt{\Delta t_{AG,1,0}^2 + \Delta t_{AG,1,fit}^2}$ }, "Seconds"]
```

```
Out[311]:= {273.536 s, 47.8362 s}
```

```
In[312]=  $\{T_{Ag,1,\frac{1}{2}}, \Delta T_{Ag,1,\frac{1}{2}}\} = \text{Log}[2] * \{t_{Ag,1}, \Delta t_{Ag,1}\}$ 
```

```
Out[312]= {189.601 s, 33.1575 s}
```

```
In[313]=  $\{t_{Ag,2}, \Delta t_{Ag,2}\} = \text{Quantity}\left[\left\{t_{Ag,2,0}, \sqrt{\Delta t_{Ag,2,0}^2 + \Delta t_{Ag,2,fit}^2}\right\}, \text{"Seconds"}\right]$ 
```

```
Out[313]= {34.2418 s, 4.17982 s}
```

```
In[315]=  $\{T_{Ag,2,\frac{1}{2}}, \Delta T_{Ag,2,\frac{1}{2}}\} = \text{Log}[2] \{t_{Ag,2}, \Delta t_{Ag,2}\}$ 
```

```
Out[315]= {23.7346 s, 2.89723 s}
```

Zerfall der Indiumisotope

Bestimmung der Zerfallskonstanten

Datenimport

```
In[289]= dataIn = Import[  
    "/Users/jannis/Dropbox/uniself/AP2/2.2/252 Aktivierung/MessungIn.dat" [[2  
    ;;, 2]]
```

```
Out[289]= {667, 672, 638, 637, 595, 637, 585, 615, 587, 547, 506,  
    560, 568, 505, 459, 492, 483, 449, 411, 466, 394, 452, 419, 419}
```

Aufbereitung der Daten

```
In[290]= errorsIn = N /@ Sqrt[dataIn]
```

```
Out[290]= {25.8263, 25.923, 25.2587, 25.2389, 24.3926, 25.2389, 24.1868, 24.7992,  
    24.2281, 23.388, 22.4944, 23.6643, 23.8328, 22.4722, 21.4243, 22.1811,  
    21.9773, 21.1896, 20.2731, 21.587, 19.8494, 21.2603, 20.4695, 20.4695}
```

```
In[291]= timesIn = Array[Quantity[120 * # + 60, "Seconds"] &, Length[dataIn]]
```

```
Out[291]= {180 s, 300 s, 420 s, 540 s, 660 s, 780 s, 900 s, 1020 s,  
    1140 s, 1260 s, 1380 s, 1500 s, 1620 s, 1740 s, 1860 s, 1980 s,  
    2100 s, 2220 s, 2340 s, 2460 s, 2580 s, 2700 s, 2820 s, 2940 s}
```

```
In[292]= valuesIn = Transpose[{timesIn // QuantityMagnitude, dataIn}];
```

Plot und Fit

```
In[293]= {aIn,0, ΔaIn,0} = ttor,In * {A0, ΔA0}
```

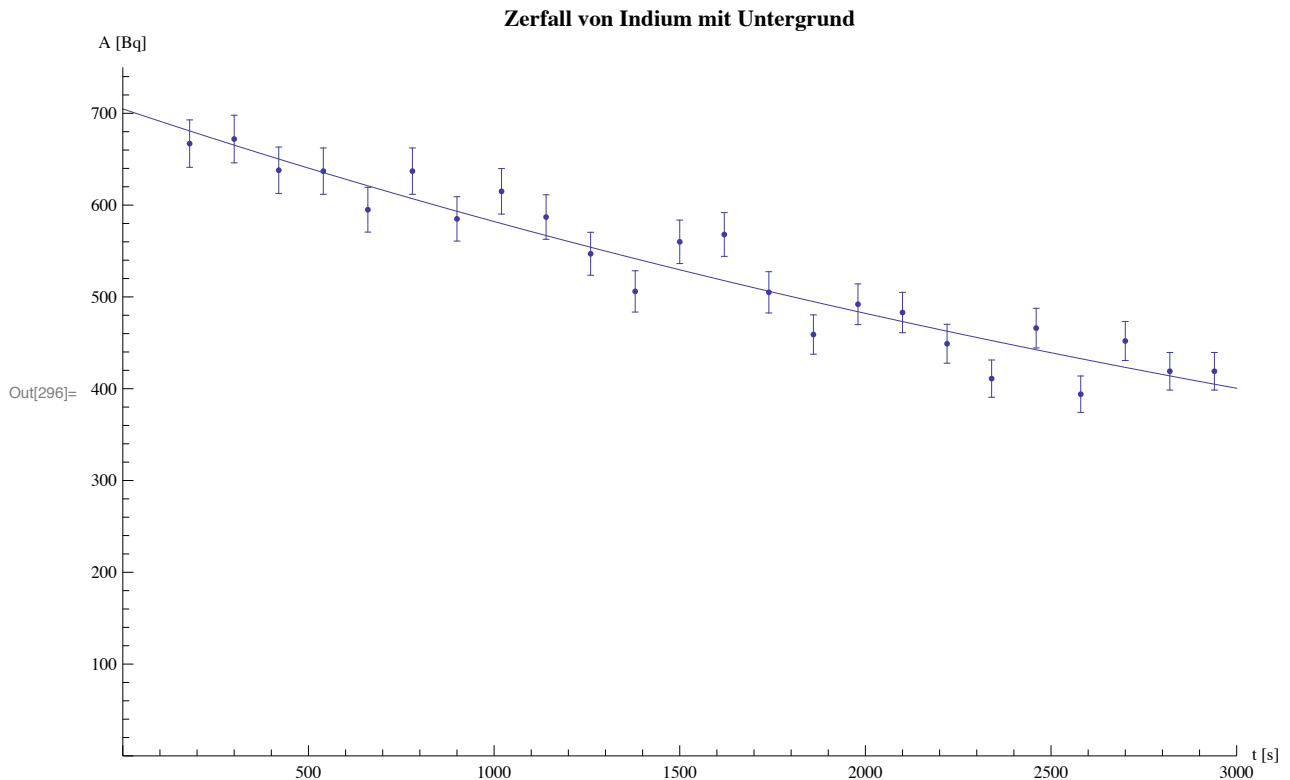
```
Out[293]= {39.7377, 23.3452}
```

```
In[294]= plotIn = ErrorListPlot[Table[{valuesIn[[i]], ErrorBar[errorsIn[[i]]]},  
    {i, 1, Length[dataIn]}, PlotRange → {{0, 3000}, {0, 750}},  
    PlotLabel → Style["Zerfall von Indium mit Untergrund", Bold],  
    AxesLabel → {"t [s]", "A [Bq]"}, ImageSize → Full, AxesOrigin → {0, 0}];
```

```
In[295]:= fitIn,0 = NonlinearModelFit[valuesIn,
  QuantityMagnitude[aIn,0 + A Exp[- $\frac{x}{t}$ ], {{A, 1000}, {t, 1000}},
  {x}, Weights  $\rightarrow \frac{1}{\text{errors}_{In}^2}$ , VarianceEstimatorFunction  $\rightarrow (1 \&)$ ]
```

```
Out[295]= FittedModel[39.7377 + 665.043 e-<<23>>x]
```

```
In[296]:= Show[plotIn, Plot[fitIn,0[x], {x, 0, 3000}]]
```



```
In[320]:= fitIn,0["ParameterTable"]
```

	Estimate	Standard Error	t-Statistic	P-Value
Out[320]= A	665.043	12.6335	52.6413	1.22196×10^{-24}
t	4904.31	279.905	17.5214	2.07522×10^{-14}

```
In[297]:= ( $\chi^2$ )In = Total[
  Table[ $\frac{(\text{values}_{In}[[i, 2]] - \text{fit}_{In,0}[\text{values}_{In}[[i, 1]])^2}{\text{errors}_{In}[[i]]^2}$ , {i, 1, Length[valuesIn]}]]]
```

```
Out[297]= 29.7704
```

```
In[322]:= Length[valuesIn]
```

```
Out[322]= 24
```

```
In[323]:= 1 - CDF[ChiSquareDistribution[Length[valuesIn] - 3]][( $\chi^2$ )In]
```

```
Out[323]= 0.0966994
```

Fehlerfortpflanzung des Fehlers auf den Hintergrund

```
In[299]= fitIn,-σ = NonlinearModelFit[valuesIn,
      QuantityMagnitude[aIn,0 - ΔaIn,0] + A Exp[- $\frac{x}{t}$ ], {{A, 700}, {t, 3600}},
      {x}, Weights →  $\frac{1}{\text{errors}_{In}^2}$ , VarianceEstimatorFunction → (1 &)]
```

```
Out[299]= FittedModel[16.3925 + 687.489 e-<<23>>x]
```

```
In[300]= fitIn,+σ = NonlinearModelFit[valuesIn,
      QuantityMagnitude[aIn,0 + ΔaIn,0] + A Exp[- $\frac{x}{t}$ ], {{A, 700}, {t, 3600}},
      {x}, Weights →  $\frac{1}{\text{errors}_{In}^2}$ , VarianceEstimatorFunction → (1 &)]
```

```
Out[300]= FittedModel[63.0829 + 642.682 e-<<23>>x]
```

```
In[301]= {tIn,0, ΔtIn,0} = fitIn,0["ParameterTableEntries"][[2, 1 ;; 2]]
```

```
Out[301]= {4904.31, 279.905}
```

```
In[302]= {tIn,-σ, ΔtIn,-σ} = fitIn,-σ["ParameterTableEntries"][[2, 1 ;; 2]]
```

```
Out[302]= {5139.36, 292.992}
```

```
In[303]= {tIn,+σ, ΔtIn,+σ} = fitIn,+σ["ParameterTableEntries"][[2, 1 ;; 2]]
```

```
Out[303]= {4669.41, 266.86}
```

```
In[304]= ΔtIn,fit = Mean[{Abs[tIn,0 - tIn,-σ], Abs[tIn,0 - tIn,+σ]}]
```

```
Out[304]= 234.976
```

Resultate

```
In[305]= {tIn, ΔtIn} = Quantity[{tIn,0,  $\sqrt{\Delta t_{In,0}^2 + \Delta t_{In,fit}^2}$ }, "Seconds"]
```

```
Out[305]= {4904.31 s, 365.459 s}
```

```
In[316]= {TIn,1/2, ΔTIn,1/2} = Log[2] {tIn, ΔtIn}
```

```
Out[316]= {3399.41 s, 253.317 s}
```