# X射线的吸收和特征谱测量实验数据处理

[redacted]

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## 1 experiment result

Because of the eq.8 we can get $\mu_m = \frac{\ln(\frac{I}{I_0})}{\rho t}$.

The corresponding element data and the least squares method of $\mu_m$ are as follows (the element types have been calibrated)

### 1.1 Absorption coefficient and actual energy of each atom's x-ray

表 1: Titanium's density =4.5 grams per $cm^3$

| Ti(sheets) | total count | time/s | count rate/$s^{-1}$ | $\ln(\frac{I}{I_0})$ | $\mu_m$ |
|---|---|---|---|---|---|
| 0 | 460842 | 50.002 | 9216.92 | 0 | 0 |
| 1 | 230323 | 50.001 | 4606.46 | -0.693581 | 0.003082582 |
| 2 | 113412 | 50.003 | 2268.104 | -1.4021 | 0.006231556 |
| 3 | 59183 | 49.998 | 1183.603 | -2.05248 | 0.009122133 |
| 4 | 27438 | 50.002 | 548.782 | -2.82109 | 0.012538178 |
| 5 | 14306 | 50.001 | 286.0628 | -3.47258 | 0.015433689 |
| 6 | 7441 | 50 | 148.82 | -4.12606 | 0.018338044 |
| 7 | 3738 | 50.003 | 74.76 | -4.81451 | 0.021397822 |

表 2: Chromium's density =7.15 grams per $cm^3$

| Ti(sheets) | total count | time/s | count rate/$s^{-1}$ | $\ln(\frac{I}{I_0})$ | $\mu_m$ |
|---|---|---|---|---|---|
| 0 | 464087 | 50.002 | 9281.74 | 0 | 0 |
| 1 | 313759 | 50.001 | 6275.18 | -0.391447123 | 0.001094957 |
| 2 | 194367 | 50.003 | 3887.34 | -0.870324496 | 0.002434474 |
| 3 | 129785 | 49.998 | 2595.7 | -1.274193657 | 0.003564178 |
| 4 | 84743 | 50.002 | 1694.86 | -1.700450031 | 0.004756504 |
| 5 | 54621 | 50.001 | 1092.42 | -2.13965505 | 0.005985049 |
| 6 | 39562 | 50 | 791.24 | -2.462204629 | 0.006887286 |
| 7 | 23606 | 50.003 | 472.12 | -2.978573121 | 0.008331673 |

表 3: Iron's density =7.874 grams per $cm^3$

| Ti(sheets) | total count | time/s | count rate/$s^{-1}$ | $\ln(\frac{I}{I_0})$ | $\mu_m$ |
|---|---|---|---|---|---|
| 0 | 136398 | 15.013 | 9086.537 | 0 | 0 |
| 1 | 103171 | 15.002 | 6877.225 | -0.278578827 | 0.002358639 |
| 2 | 78670 | 15 | 5244.517 | -0.549611087 | 0.004653383 |
| 3 | 58590 | 14.995 | 3907.636 | -0.843861848 | 0.007144711 |
| 4 | 50531 | 15.015 | 3365.901 | -0.993098852 | 0.008408254 |
| 5 | 35912 | 15 | 2394.293 | -1.333706776 | 0.011292073 |
| 6 | 27654 | 15.001 | 1843.052 | -1.595372047 | 0.01350751 |
| 7 | 21061 | 15 | 1403.786 | -1.867622251 | 0.015812567 |

There are 16 groups of constants c and d, which are not listed here, only the final fitting results are given.

c=0.1014(05)

d=1.0463(04)

表 4: Zinc's density =7.13 grams per $cm^3$

| Ti(sheets) | total count | time/s | count rate/$s^{-1}$ | $\ln(\frac{I}{I_0})$ | $\mu_m$ |
|---|---|---|---|---|---|
| 0 | 85394 | 10.008 | 8532.573941 | 0 | 0 |
| 1 | 78361 | 9.981 | 7851.016932 | -0.083248062 | 0.001167574 |
| 2 | 69123 | 9.988 | 6920.604726 | -0.209388061 | 0.002936719 |
| 3 | 63527 | 10.004 | 6350.159936 | -0.295411274 | 0.004143216 |
| 4 | 52183 | 10 | 5218.3 | -0.491719727 | 0.00689649 |
| 5 | 49015 | 10.013 | 4895.136323 | -0.555649323 | 0.007793118 |
| 6 | 48332 | 10.005 | 4830.784608 | -0.568882558 | 0.007978718 |
| 7 | 38322 | 10.007 | 3829.519336 | -0.801152318 | 0.011236358 |

表 5: Copper's density =8.96 grams per $cm^3$

| Ti(sheets) | total count | time/s | count rate/$s^{-1}$ | $\ln(\frac{I}{I_0})$ | $\mu_m$ |
|---|---|---|---|---|---|
| 0 | 88606 | 10.006 | 8855.487 | 0 | 0 |
| 1 | 85422 | 9.989 | 8851.707 | -0.003808952 | 4.25106E-05 |
| 2 | 67359 | 9.988 | 6736.974 | -0.276808595 | 0.003089382 |
| 3 | 57737 | 10.004 | 5780.637 | -0.429905677 | 0.004798054 |
| 4 | 51256 | 10.012 | 5119.856 | -0.551293329 | 0.007689389 |
| 5 | 44664 | 10.013 | 4461.346 | -0.688969221 | 0.007793118 |
| 6 | 40861 | 9.988 | 4090.8 | -0.775679243 | 0.008657134 |
| 7 | 33392 | 9.989 | 3343.117 | -0.977515726 | 0.010909774 |

表 6: Germanium's density =5.323 grams per $cm^3$

| Ti(sheets) | total count | time/s | count rate/$s^{-1}$ | $\ln(\frac{I}{I_0})$ | $\mu_m$ |
|---|---|---|---|---|---|
| 0 | 87757 | 9.998 | 8832.699 | 0 | 0 |
| 1 | 86640 | 9.989 | 8717.089 | -0.013175287 | 0.000247516 |
| 2 | 74527 | 10.001 | 7489.651 | -0.16493854 | 0.003098601 |
| 3 | 72191 | 9.988 | 7264.017 | -0.19552778 | 0.003673263 |
| 4 | 66597 | 10.006 | 6085.749 | -0.372511073 | 0.006998142 |
| 5 | 59007 | 10.002 | 5930.414 | -0.398366873 | 0.007483879 |
| 6 | 58931 | 10.004 | 5921.831 | -0.399815208 | 0.007511088 |
| 7 | 50521 | 9.989 | 5084.893 | -0.552187015 | 0.010373605 |

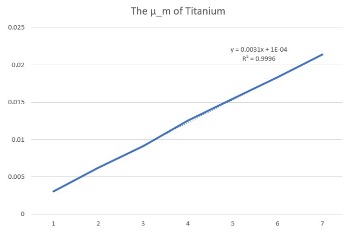


图 1: Titanium

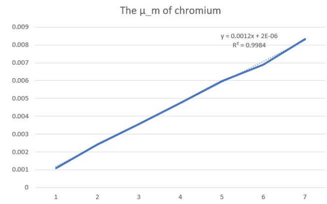


图 2: chromium

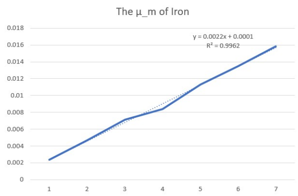


图 3: Iron

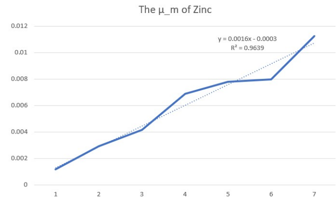


图 4: Zinc

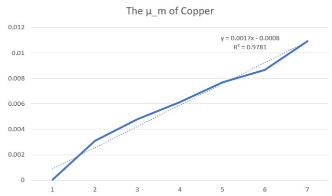


图 5: Copper

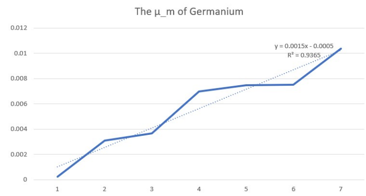


图 6: Germanium

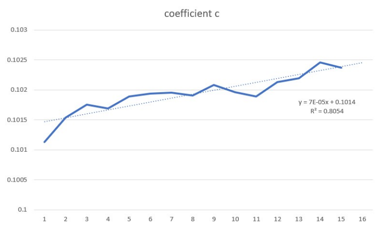


图 7: constant c

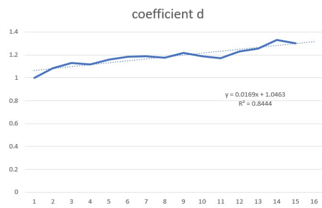


图 8: constant d

So that we can use these constants back to formula $(h\nu)^{\frac{1}{2}} = 0.1014(Z - 1.0463)$, substitute the data in the table. It can be found that the formula corresponds very well to the atoms in the table.

## 1.2 unknown atoms

We can use peaks by above 6 atoms to comfirm this 3 unknown atoms.

表 7: The energy table of each atom's eigen x-ray

| atomic number | atom | $K\alpha$ theoretical | $K\alpha$ experimental |
|---|---|---|---|
| 22 | Titanium | 4.51 | 4.51437 |
| 23 | Vanadium | 4.95 | 4.955544 |
| 24 | Chromium | 5.41 | 5.41728 |
| 25 | Manganese | 5.895 | 5.89958 |
| 26 | Iron | 6.40 | 6.40244 |
| 27 | Cobalt | 6.925 | 6.92587 |
| 28 | Nickel | 7.47 | 7.469861 |
| 29 | Copper | 8.04 | 8.034419 |
| 30 | Zinc | 8.63 | 8.619539 |
| 31 | Gallium | 9.24 | 9.225222 |
| 32 | Germanium | 9.876 | 9.8514702 |

| | |
|---|---|
| 2736.68 | 4.51 |
| 3284.74 | 5.41 |
| 3886.23 | 6.4 |
| 5239.89 | 8.63 |
| 4881.91 | 8.04 |
| 5996.87 | 9.876 |

Then we get these three unknown atoms' $K\alpha$, each of them is:4.95198KeV, 6.92869KeV, 7.47094KeV. And compare with the table, finally we know that these 3 unknown atoms are: Vanadium, Cobalt, Nickel.

# 2 Thinking

1.By eq.10 $E = Z^2 \frac{2\pi m_0 e^4}{h^2}(\frac{1}{n_1^2} - \frac{1}{n_2^2}) = 2.7863 \times 10^{-16} eV$, so the Plutonium source can excite Silver's $K\alpha$ line.

2.Yes. Because $\sigma_T = 0.6651 \times 10^{-24} b$, $\sigma_{ph} = 1.38 \times 10^{-26} b$, so the Thomson cross section is important.

3.Consider a non-ideal collimation beam as a ideally collimated beam at an angle, then suppose the angle of incidence is $\theta$, then eq.8 will become $I(t) = I_0 e^{-\mu\rho \frac{t}{\cos\theta}}$

So when the divergence angle are 10° and 25°, the $\mu$ of Aluminium are

$$\mu_{10^\circ} = \frac{\mu}{\cos 10^\circ}$$

$$\mu_{25^\circ} = \frac{\mu}{\cos 25^\circ}$$

# 3 appendix-code

```
#code1
import numpy as np
import sympy as sym

#(eV)**(1/2)==c(Z-d)
#use cycle to calculate!!
Ti1,Ti2 = 22,4.51
Cr1,Cr2 = 24,5.41
Fe1,Fe2 = 26,6.4
Zn1,Zn2 = 30,8.63
Cu1,Cu2 = 29,8.04
Ge1,Ge2 = 32,9.876


c,d = sym.symbols('c,d')
eq1= sym.Eq(c*(Cu1-d),(Cu2)**0.5)
eq2 = sym.Eq(c*(Ge1-d),(Ge2)**0.5)
result = sym.solve([eq1,eq2],(c,d))
print(result)
####
#code2
import numpy as np
import sympy as sym

```

```
#(eV)**(1/2)==c(Z-d)
#use cycle to calculate!!
Ti1,Ti2 = 22,4.51
V = 23
Cr1,Cr2 = 24,5.41
Mn = 25
Fe1,Fe2 = 26,6.4
Co = 27
Ni = 28
Cu1,Cu2 = 29,8.04
Zn1,Zn2 = 30,8.63
Ga = 31
Ge1,Ge2 = 32,9.876



eq1= (0.1014*(Ti1-1.0463))**2

print(eq1)
```

Listing 1: alpha