Determination of the Light Elements in Metals: A Bibliography of Activation Analysis Papers
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Determination of the Light Elements in Metals: A Bibliography of Activation Analysis Papers

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W. Wayne Meinke, Chief
Analytical Chemistry Division
DETERMINATION OF THE LIGHT ELEMENTS IN METALS:
A BIBLIOGRAPHY OF ACTIVATION ANALYSIS PAPERS

G. J. Lutz, Editor

References to the Determination of the Light Elements in Metals using Activation Analysis are indexed according to the elements boron, carbon, nitrogen, oxygen, phosphorous, silicon and sulfur. The indexes are arranged by Element Determined and subdivided according to Matrices and Nuclear Reactions involved. An Author Index is included.

Key words: Boron; carbon; light elements; metals; nitrogen; oxygen; phosphorous; silicon; sulfur.

INTRODUCTION

This publication, Determination of the Light Elements in Metals: A Bibliography of Activation Analysis Papers, is the second in a series of specialized bibliographies on Activation Analysis prepared by the Analytical Chemistry Division Activation Analysis Information Center.

Publications obtained by the Center for inclusion in the Activation Analysis file are indexed according to the broad categories of Element Determined, Matrix Analyzed and Technique Used. Currently there are 106 descriptive terms under Matrix Analyzed and 53 under Technique Used.

Items included in this bibliography were extracted from the Elements Determined: Boron, Carbon, Nitrogen, Oxygen, Phosphorous, Silicon and Sulfur and from the appropriate keys of Matrix Analyzed dealing with metals. The form of the indexes is by Element Determined with listings of Matrices and Nuclear Reactions involved.
An author index has been included and it is hoped that readers will point out omissions to the editor. The Center plans to publish revisions to this bibliography commensurate with the growth of the field.
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STEEL 1821 3466 5408 5932 7361

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ALUMINUM 4 578 688 703 767
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CALCIUM 1816
CESIUM 4386
GERMANIUM 1604 6752 7015
GOLD 105 1599 1831 7011
IRON 4 8 401 417 703 744 1219 5954 7015 7018
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MOLYBDENUM 3070 6742
NICKEL 1604 6593 6752
NIOBium 7015
PLATINUM 7011
SILICON 1831 6581 6593 6736 7019 7307
SILVER 105
SODIUM 1560 1816
STEEL 118 119 351 1026 1604 1951 2652 5238 6742 6752 7162

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TANTALUM 1604 3977 6752 7015
TERBIUM 4226
TUNGSTEN 3070
ZIRCONIUM 703 1604 6752

NITROGEN

ALUMINUM 703
BERYLLIUM 49 703 1263 1816 2505 3070 3976
IRON 7015
METALS, GENERAL 5238 7213 7343
MOLYBDENUM 3070
NIOBium 5782 7015
SILICON 7019
TUNGSTEN 3070
ZIRCONIUM 703 760

OXYGEN

ALUMINUM 578 654 655 1067 1589 1804 3721 3722 3771 3992 4211 5409 5432 5772 5921 6591 6694 6978 7012
AMERICIUM 4226
BERYLLIUM 45 46 49 58 108 109 391 500 578 596 814 1103 1104 1263 1318 1816 2505 2549 2686 3070 3073 3090 3727 3976 4277 7097 7214
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BORON 1816 4260
CADMIUM 5772
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CESIUM 131 4386
CHROMIUM 500 3090 6591 7230

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<td>105 1318 1730</td>
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<td>Tin</td>
<td>500</td>
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<tr>
<td>Titanium</td>
<td>426 1067 1103 1739 3357 3981</td>
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<td></td>
<td>4277 5431 5772 5781 6750</td>
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<tr>
<td>Tungsten</td>
<td>500 1067 2381 3070 3768 5938</td>
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<tr>
<td></td>
<td>6590</td>
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<tr>
<td>Vanadium</td>
<td>500</td>
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<tr>
<td>Zinc</td>
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<tr>
<td>Zircoaly</td>
<td>426 1067 1309 3768</td>
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<td>Zirconium</td>
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<td>3721 4277 5772 5938 6590 6595</td>
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<td>6752 7012 7200</td>
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**Phosphorous**

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<tr>
<td>Aluminum</td>
<td>4 161 398 688 767 979 2550 6410</td>
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<tr>
<td>Aluminum-Silicon Alloys</td>
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<td>Antimony</td>
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<td>Copper</td>
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<td>Iron</td>
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<td>22 6410</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>7145</td>
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<tr>
<td>Nickel</td>
<td>892 6568</td>
</tr>
<tr>
<td>Nickel Alloys</td>
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II-4
DETERMINATION OF LIGHT ELEMENTS
IN METALS - MATRIX INDEX

PHOSPHOROUS (CONTINUED)

<table>
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<tr>
<th>Element</th>
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<tr>
<td>NIOBium</td>
<td>641 1165 1709</td>
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<tr>
<td>SELENIUM</td>
<td>1215 1520 6446</td>
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<tr>
<td>SILICON</td>
<td>244 246 255 509 892 1118 1166 2386 2523 6226 6572</td>
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<tr>
<td>STEEL</td>
<td>893 1085 1124 2764 6086</td>
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</tr>
<tr>
<td>TUNGSTEN</td>
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<tr>
<td>ZIRCONIUM</td>
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SILICON

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<td>BERYLLIUM</td>
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<td>IRON</td>
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<td>NIOBium</td>
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<tr>
<td>STEEL</td>
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<td>TITANIUM</td>
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<tr>
<td>ZIRCONIUM</td>
<td>1709</td>
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SULFUR

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<td>ALUMINUM</td>
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<td>CHROMIUM</td>
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<td>COPPER</td>
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<td>GOLD</td>
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<td>6410 6412 6568</td>
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II-5
SULFUR (CONTINUED)

<table>
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<td>STEEL</td>
<td>893 1085 1124 1711 2764 6086</td>
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<td>ZIRCONIUM</td>
<td>1471 1709 2550</td>
</tr>
</tbody>
</table>

APPENDIX III
### DETERMINATION OF LIGHT ELEMENTS IN METALS - REACTION INDEX

**BORON**

\[
\begin{align*}
11^B(p,n)11^C & \quad 181 \ 1013 \ 1091 \ 2712 \\
10^B(d,n)11^C & \quad 2712 \\
10^B(n,\alpha)^7Li & \quad 1546 \ 1547 \ 1561 \ 1618 \ 1787 \ 3059 \\
  & \quad \text{electronic } \alpha \text{ counting} \quad 3361 \ 5429 \\
10^B(n,\alpha)^7Li & \quad 5408 \ 5932 \\
  & \quad \text{track counting} \\
10^B(n,\alpha)^7Li & \quad 1546 \ 1547 \ 1561 \ 1361 \ 3466 \ 5919 \\
  & \quad \text{neutron flux depression} \quad 1821 \\
10^B(n,\alpha)^7Li & \quad 7285 \ 7361 \\
  & \quad \text{prompt } ^7Li \text{ gamma ray} \\
\text{Deuteron bombardment} & \quad 3976 \\
\end{align*}
\]

**CARBON**

\[
\begin{align*}
12^C(d,n)^{13}N & \quad 4 \ 8 \ 118 \ 119 \ 417 \ 688 \ 744 \ 767 \\
 & \quad 1219 \ 1951 \ 2505 \ 3070 \ 3976 \ 5238 \\
  & \quad 6581 \ 6736 \ 7307 \\
12^C(\gamma,n)^{11}C & \quad 45 \ 46 \ 49 \ 351 \ 703 \ 1263 \ 1560 \ 1816 \\
  & \quad 3727 \ 4386 \ 5954 \ 6593 \ 6742 \ 7015 \\
  & \quad 7017 \ 7018 \\
12^C(^3He,\alpha)^{11}C & \quad 105 \ 1599 \ 1604 \ 1831 \ 3977 \ 4226 \\
  & \quad 6752 \ 7011 \ 7019 \ 7162 \\
12^C(p,\gamma)^{13}N & \quad 401 \ 744 \ 1026 \ 1219 \\
12^C(\alpha,\alpha n)^{11}C & \quad 578 \\
12^C(d,p)^{13}C & \quad \text{(prompt } \gamma \text{ detection)} \quad 2652 \\
\end{align*}
\]

III-1
### Determination of Light Elements in Metals - Reaction Index

#### Nitrogen

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Energies (MeV)</th>
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</thead>
<tbody>
<tr>
<td>$^{14}_N(\gamma,n)^{13}_N$</td>
<td>49 703 760 1263 1816 7015</td>
</tr>
<tr>
<td>$^{14}_N(d,n)^{15}_O$</td>
<td>2505 3070 3976</td>
</tr>
<tr>
<td>$^{14}_N(d,n)$ - prompt neutron detection</td>
<td>5238</td>
</tr>
<tr>
<td>$^{14}_N(n,2n)$ - C-W generator</td>
<td>5782</td>
</tr>
<tr>
<td>$^{14}_N(p,a)^{11}_C$</td>
<td>7019</td>
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</tbody>
</table>

#### Oxygen

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Energies (MeV)</th>
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<tbody>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>108 109 131 426 500 596 762</td>
</tr>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>1067 1103 1104 1309 1394 1453</td>
</tr>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>1589 1739 1804 1900 1950 1956</td>
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<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>2418 2505 2507 2526 2542 2549</td>
</tr>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>2586 2598 2615 2649 2678 2686</td>
</tr>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>2734 2764 2798 2802 2983 3073</td>
</tr>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>3085 3090 3357 3502 3746 3768</td>
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<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>3981 4260 5321 5380 5409 5431</td>
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<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>5432 5451 5452 5708 5772 5781</td>
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<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>6694 6705 6728 6750 6856 6978</td>
</tr>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>7076 7097 7142 7214 7289 7291</td>
</tr>
<tr>
<td>$^{16}_O(n,p)^{16}_N$ - 14 MeV neutrons from Cockcroft Walton generator</td>
<td>7330 7344 7387 7417 7419</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Energies (MeV)</th>
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<tbody>
<tr>
<td>$^{16}_O(a,pn)^{18}_F$</td>
<td>578 1151 1194 1742 2381 3722</td>
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<td>$^{16}_O(a,pn)^{18}_F$</td>
<td>5921 5938 6590 6591 6593 7015</td>
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<td>$^{16}_O(a,pn)^{18}_F$</td>
<td>7230 7248</td>
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</tbody>
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<table>
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<th>Reaction</th>
<th>Energies (MeV)</th>
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<tr>
<td>$^{18}_O(p,n)^{18}_F$</td>
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<tr>
<td>$^{18}_O(p,n)^{18}_F$</td>
<td>4277</td>
</tr>
<tr>
<td>$^{18}_O(p,n)^{18}_F$</td>
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<tr>
<td>$^{16}_O(n,p)^{16}_N$ - reactor neutrons</td>
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<tr>
<td>$^{16}_O(d,n)^{17}_F$</td>
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</tr>
<tr>
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</tbody>
</table>

III-2
DETERMINATION OF LIGHT ELEMENTS IN METALS – REACTION INDEX

OXYGEN (Continued)

\[ {\text{^{16}O}}(\gamma, n) {\text{^{15}O}} \]
\[ 45 \ 46 \ 49 \ 58 \ 814 \ 1263 \ 1816 \ 3727 \]
\[ 3771 \ 4386 \ 6742 \ 7015 \ 7017 \ 7106 \]

\[ {\text{^{16}O}}({\text{^3He}}, p) {\text{^{18}F}} \]
\[ 105 \ 1318 \ 1604 \ 1831 \ 2381 \ 3721 \]
\[ 3977 \ 4211 \ 4226 \ 5921 \ 5938 \ 6053 \]
\[ 6072 \ 6590 \ 6752 \ 7011 \ 7015 \ 7019 \]
\[ 7230 \ 7248 \]

\[ {\text{^{16}O}}(t, n) {\text{^{18}F}}; \text{tritons from} \ {\text{^6Li}}(n, \alpha)t \]
\[ 391 \ 654 \ 655 \ 1158 \ 1730 \ 2562 \ 3992 \]

PHOSPHOROUS

\[ {\text{^{31}P}}(n, \gamma) {\text{^{32}P}} \]
\[ 4 \ 22 \ 140 \ 161 \ 223 \ 244 \ 246 \ 255 \]
\[ 398 \ 509 \ 641 \ 688 \ 767 \ 864 \ 892 \ 893 \]
\[ 979 \ 985 \ 1085 \ 1118 \ 1124 \ 1165 \ 1166 \]
\[ 1193 \ 1215 \ 1471 \ 1477 \ 1520 \ 1709 \]
\[ 2386 \ 2523 \ 2550 \ 2721 \ 2764 \ 6086 \]
\[ 6226 \ 6410 \ 6412 \ 6446 \ 6568 \ 6572 \]
\[ 7145 \ 7172 \]

SILICON

proton scattering
\[ {\text{^{28}Si}}(n, \gamma) {\text{^{29}Si}} \]
\[ 2429 \]
\[ 4 \ 81 \ 102 \ 417 \ 452 \ 641 \ 850 \ 1263 \]
\[ 1709 \ 6086 \ 7407 \]

\[ {\text{^{28}Si}}(n, p) {\text{^{28}Al}} \]
\[ \text{C-W Generator} \]
\[ 628 \ 1875 \ 2596 \ 6398 \ 6723 \ 6844 \ 7170 \]

\[ {\text{^{28}Si}}(n, p) {\text{^{28}Al}} \]
\[ \text{Po-Be source} \]
\[ 1590 \ 1591 \]

SULFUR

\[ {\text{^{34}S}}(n, \gamma) {\text{^{35}S}} \]
\[ 22 \ 140 \ 641 \ 688 \ 767 \ 892 \ 893 \ 1085 \]
\[ 1124 \ 1193 \ 1215 \ 1378 \ 1471 \ 1477 \]
\[ 1520 \ 1621 \ 1711 \ 2550 \ 6086 \ 6410 \]
\[ 6446 \ 6568 \]

\[ {\text{^{32}S}}(n, p) {\text{^{32}P}} \]
\[ 704 \ 1520 \ 1570 \ 1709 \ 1965 \ 2764 \]
\[ 4300 \ 6412 \ 6446 \ 6568 \ 7172 \]

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