**纯铝化学分析方法**

**痕量杂质元素含量的测定**

**辉光放电质谱法**

**编制说明**

(送审稿)

主编单位：国标（北京）检验认证有限公司

2022年7月

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**一 工作简况**

**1.1 任务来源**

根据中华人民共和国工信部工信厅科函（2020）263号文件，由国标（北京）检验认证有限公司（原北京有色金属研究总院分析测试技术研究所）对行业标准YS/T 871《纯铝化学分析方法 痕量杂质元素含量的测定 辉光放电质谱法》进行修订，计划号为2020-1525T-YS，计划完成年限为2022年。

**1.2 项目编制工作组单位介绍和主要负责人及参与人负责的工作。**

本标准项目编制工作主要由国标（北京）检验认证有限公司牵头修订工作，参与牵头修订工作单位有新疆众和股份有限公司、昆明冶金研究院、金川集团股份有限公司、包头铝业有限公司，深圳市万泽中南研究院有限公司。

其中国标（北京）检验认证有限公司负责统一样品的收集和分发，分析方法的实验研究，样品测试结果的收集和处理，标准文本、试验报告和编制说明的撰写。新疆众和股份有限公司为一验单位，负责对试验报告中的条件实验进行验证，提供精密度和准确度测试数据，并对标准文本提出修改意见。昆明冶金研究院、金川集团股份有限公司、包头铝业有限公司，深圳市万泽中南研究院为二验单位，负责提供精密度试验数据，并对标准文本提出修改意见。样品提供单位为新疆众和股份有限公司和包头铝业有限公司。本文件主要起草单位负责人及参与人员主要职责见表1

表1 参与人员与主要职责

|  |  |
| --- | --- |
| 参与人员 | 主要职责 |
| 李爱嫦，墨淑敏，王长华，潘元海，邱长丹，祝利红，郑佳乐 | 标准工作前期调研、申报、样品搜集、实验方案的确定、标准文本和编制说明的编写、数理统计计算重复性限和再现性限 |
| 宋玉萍，肖丽梅 | 承担一验的主要工作，包括对实验条件试验、实验步骤、试剂材料等的验证，并进行实验样品精密度试验并提供精密度数据标准文本、编制说明提出修改意见。 |
| 杨海岸，刘英波，张晓平，秦芳林，温炜炜，陈芳 | 承担二验的主要工作，进行实验样品精密度试验并提供精密度数据，对标准文本、编制说明提出修改意见。 |

国标（北京）检验认证有限公司作为国合通用测试评价认证股份公司的全资子公司，前身是北京有色金属研究总院分析测试技术研究所，是国家有色金属行业最知名的第三方检验机构。国标（北京）检验认证有限公司运营管理着国家有色金属及电子材料分析测试中心和国家有色金属质量监督检验中心，拥有一支基础理论扎实、实践经验丰富的研究和服务队伍，自2004年至今共承担了国家科技支撑计划、国家863计划、国家自然科学基金、军工配套等省部级科技项目40余项；曾获国家科技进步奖6项，国家发明奖3项，省部级科技进步一等奖10项，二、三等奖107项；近5年获得国家发明专利20余项；负责和参加起草制订分析方法国家标准和行业标准300余项；国家标准物质/标准样品120个，在国内外科技期刊上发表论文800余篇，撰写论著22部。

**1.3主要工作过程**

**1.3.1起草阶段**

**（1）任务落实**

全国有色金属标准化技术委员会在2021年4月20日～4月22日在贵州省贵阳市召开了有色金属标准项目论证会暨标准制修订工作会议。全国有色金属标准化技术委员会、国标（北京）检验认证有限公司、新疆众和股份有限公司、昆明冶金研究院、金川集团股份有限公司、包头铝业有限公司等多家单位的代表参加了会议。经专家组开会讨论决定国标（北京）检验认证有限公司为YS/T 871《纯铝化学分析方法 痕量杂质元素含量的测定 辉光放电质谱法》主要起草单位，新疆众合股份有限公司、昆明冶金研究院、金川集团股份有限公司、包头铝业有限公司和深圳市万泽中南研究院有限公司作为验证单位，新疆众合股份有限公司和包头铝业有限公司为标准研制提供样品，完成年限为2022年。

**（2）标准制定过程**

国标（北京）检验认证有限公司在任务落实工作会议之后，立即组织骨干人员成立了标准编制组，根据立项阶段前期调研的实验方案和数据制定了具体的研究内容、技术路线、任务分工和进度安排。主要工作过程安排如下：

2021年4月~5月草单位完成样品采集工作；

2020年5月~2021年6月主起草单位完成主要试验工作，形成征求意见稿，并将试验报告和样品发给各验证单位；

2021年6月~2021年10月验证单位完成验证工作，将验证报告返给主起草单位，主起草单位进行数理统计，形成标准讨论稿；

2021年10月~2021年12月根据各参与单位意见，根据起草和验证单位提供数据再次进行数理统计，计算重复性限和再现性限，完善标准文本，形成标准预审稿；

2022年3月10日起草单位和验证单位参加了全国轻金属标准化技术委员会组织召开的标准网络预审会。会上新疆众合股份有限公司、昆明冶金研究院、金川集团股份有限公司、包头铝业有限公司、广州有色院、郑轻院等单位的几十余位专家代表对本标准预审稿提出了修改意见。

2022年3月~6月起草单位根据预审会各位专家的意见对预审稿进行修改，形成送审稿。

2022年7月11日起草单位和验证单位参加了全国轻金属标准化技术委员会组织召开的标准网络审定会。会上新疆众合股份有限公司、昆明冶金研究院、金川集团股份有限公司、包头铝业有限公司、广州有色院、郑轻院等单位的几十余位专家代表对本标准送审稿提出了修改意见。

**1.3.2征求意见阶段**

（1）标准编制组通过中国有色金属标准质量信息网上公开、发函、会议等形式对《纯铝化学分析方法 痕量杂质元素含量的测定 辉光放电质谱法》进行征求意见。

（2）在征求意见阶段，起草单位将征求意见稿发送至22家单位。其中收到征求意见稿后，回函的单位数为22个，回函并有建议或意见的单位数为7个，没有回函的单位数为0个。编制组依据各家单位的意见和对标准文本进行修改，最后形成本标准的送审稿。

**二 编制原则和依据**

**2.1 符合性**

标准负责起草单位在任务落实会上广泛地征求了与会专家和代表的意见，确定了制订的方案；确定了标准起草原则、主要内容框架和依据,本文件严格按照GB/T 1.1-2020《标准化工作导则 第1部分：标准化文件的结构和起草规则》、GB/T 20001.4-2015《标准编写规则 第4部分：试验方法标准》、GB/T 6379。2-2004《测量方法与结果的准确度》的要求进行编制。

**2.2 适用性和先进性**

本标准编制组为做到标准的先进性与实用性，查询相关国内外相关产品和分析方法标准和收集国内外客户的相关技术要求，并根据目前国内纯铝生产企业的具体情况及技术水平，结合分析技术发展，力求做到标准的合理性、实用性，与时俱进；

目前分析方法GB/T 20975《铝及铝合金化学分析方法》是针对铝及铝合金中待测元素含量在微量和常量范围的分析方法；已修订完成的YS/T 870-2020《高纯铝化学分析方法 痕量杂质元素含量的测定 电感耦合等离子体质谱法》主要是针对杂质元素含量在微量及痕量范围的分析方法，可以满足产品标准GB/T 1196《重熔用铝锭》和YS/T 665《重熔用精铝锭》中化学成分的要求。而产品标准YS/T 275《纯铝锭》和GB/T 33912 《高纯金属为原料的变形铝及铝合金铸锭》中存在某些上述分析方法未解决的元素，可以通过修订YS/T 871-2013《高纯铝化学分析方法痕量杂质元素的测定 辉光放电质谱法》，解决上述问题，以此完善铝的整个分析方法标准体系，更加全面高效地对纯铝的化学成分做出评价，保证产品质量，服务铝行业生产。

**三 主要内容分析**

纯铝GDMS方法标准小组查阅大量文献资料和国内外标准，并且依据市场客户检测的需求，最终确定了实验方案。修订内容的主要变化如下：

(1).产品标准YS/T 275《纯铝锭》和GB/T 33912《高纯金属为原料的变形铝及铝合金铸锭》中存在现有的标准分析方法未解决的元素；当前纯铝技术不断发展和应用，许多客户要求对纯铝样品进行GDMS全元素分析，YS/T 871-2013只有39种元素，待测元素由39种元素Li、Be、B、Na、Mg、Al、Si、P、K、Ca、Ti、V、Cr、Mn、Fe、Ni、Co、 Zn、Ga、Ge、As、Se、Sr、Zr、Ag、Cd、In、Sn、Sb、Cs、Ba、Ce、W、Pt、Au、Pb、Bi、Th、U增加元素F、S、Cl、Sc、Br、Rb、Y、Nb、Mo、Ru、Rh、Pd、Te、I、La、Pr、Nd、Sm、Eu、Gd、Tb、Dy、Ho、Er、Tm、Yb、Lu、Hf、Ta、Re、Os、Ir、Hg、Tl(34种)至73种元素。硫，氯为0.05 mg/kg ~10mg/kg，其它元素测定范围为0.005 mg/kg ~10mg/kg。

(2).国外关于纯铝辉光放电质谱的标准有美国材料与试验协会标准ASTM F 1593-08《Standard Test Method for Trace Metallic Impurity in Electronic Grade Aluminium by High Mass-Resolution Glow-Discharge Mass Spectrometer》现行GDMS标准已在2016年进行重新审核，并没有对主要技术内容进行修改，测定纯铝中24个元素。本标准结合国际先进标准ASTM F 1593-08和SEMI PV1-0709《Test method for measuring trace elements in silicon feedstock for silicon solar cells by high-mass resolution glow discharge mass spectrometry》 对标准的文本的文字性概念如检出限描述进行修订，保证与国际先进标准的一致性。

**3.1实验原理**

试料铝作为阴极在惰性气体氩气的保护下，在高压溅射下进行辉光放电，其表面原子被溅射而脱离试料进入辉光放电等离子体中，离子化后再被导入质谱仪中进行测定。在每一元素同位素质量数处以预设的扫描点数和积分时间对相应谱峰积分，所得面积即为谱峰强度。在缺少标准样品时，计算机根据仪器软件中的“典型相对灵敏度因子”自动计算出各元素的质量分数；有标准样品时，则需要通过在与被测样品相同的分析条件、离子源结构以及测试条件下对标准样品进行独立测定获得相对灵敏度因子，应用该相对灵敏度因子计算出各元素的质量分数。

被测元素的含量以质量分数*w*x计，以µg/kg表示，按公式（1）计算：

……………………………… (1)

式中：

*w*x—— 待测元素质量分数，单位为微克每千克µg/kg

*RSF*(x/Al)——在特定辉光放电条件下测定Al中X元素的校正系数，即“典型相对灵敏度因子”

*I*x—— 待测元素X的同位素谱峰强度，cps

*I*Al——元素的同位素谱峰强度，cps

*A*Al——Al元素的同位素丰度

*A*x——待测元素X的同位素丰度

*W*Al——Al的质量分数定义为1.00×109，µg/kg。

**3.2主要仪器**

仪器： ELEMENT GD 高分辨辉光放电质谱仪 美国 Thermo Fisher公司

（工作参数：如表1所示）

表1 GDMS仪器参数

|  |  |
| --- | --- |
| Discharge current | 65mA |
| Discharge voltage | 780V |
| Discharge gas | 380mL/min |
| Ion source cooling temperature | 13℃ |

**3.3主要试剂**

5N纯铝(新疆众和股份有限公司提供5NAl样品)；

4N纯铝（包头铝业有限公司提供4NAl样品）；

盐酸（MOS级，北京化学试剂研究所）；

硝酸（MOS级，北京化学试剂研究所）；

乙醇（MOS级，北京化学试剂研究所）；

去离子水（电阻率>16MΩ·cm）；

高纯氩气（纯度不小于99.9995%）；

高纯氮气（纯度不小于99.999%）；

锥(石墨)、导流管(石墨)，阳极帽(石墨)、陶瓷圈。

**3.4实验操作**

**3.4.1样品制备与处理**

将样品处理成直径在20～70mm，高为2～70mm的圆柱型或者正方形（或者至少有一平面）的样品。用乙醇清洗样品表面上的油污，再用超纯水清洗，用50%盐酸腐蚀8min，用超纯水反复冲洗后，分析前用高纯氮气吹干放入GDMS的样品架固定后进行分析。

**3.4.2样品预溅射**

把样品放入样品架中固定，依次将锥(石墨)、导流管(石墨)，陶瓷帽，阳极帽(石墨)安装好，将样品架推入离子源腔内启动GD on待真空度达到2.2mbar，调节放电电压和放电电流分别为780V、65mA，欲溅射约15min，以消除样品制备过程中可能产生的沾污。

**3.4.3半定量测定**

调节放电电压为780V，放电电流为65mA，进行高压放电，收集待测元素离子信号，根据辉光放电质谱仪半定量分析原理，求出待测杂质元素的含量。

**3.5结果与讨论**

**3.5.1 工作参数**

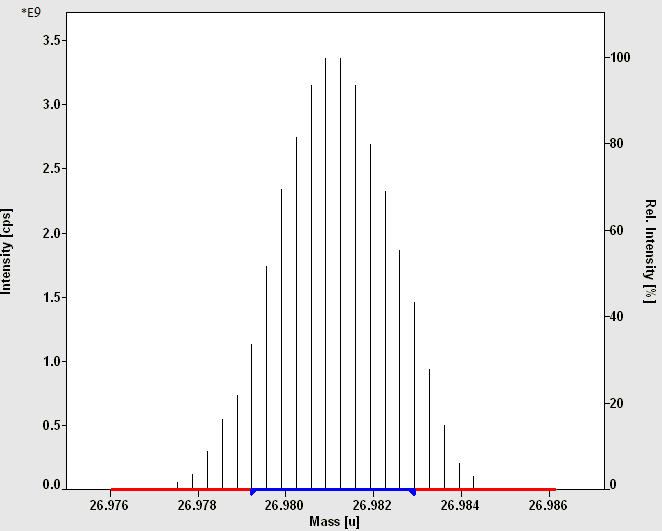
放电条件直接影响测定的进行，在中分辨率和高分辨率对离子源的放电电压和放电电流分别进行调谐，当放电电压和放电电流较大时容易使阴极样品温度过高，从而导致短路，当放电电压和放电电流较低时，样品的信号峰有较大拖尾，经反复调谐，仪器的参数如表1中所示。调节其它Lenses参数使中分辨率达到4000，在高分辨率分辨率达到10000左右。

图1 中分辨下基体Al的信号峰

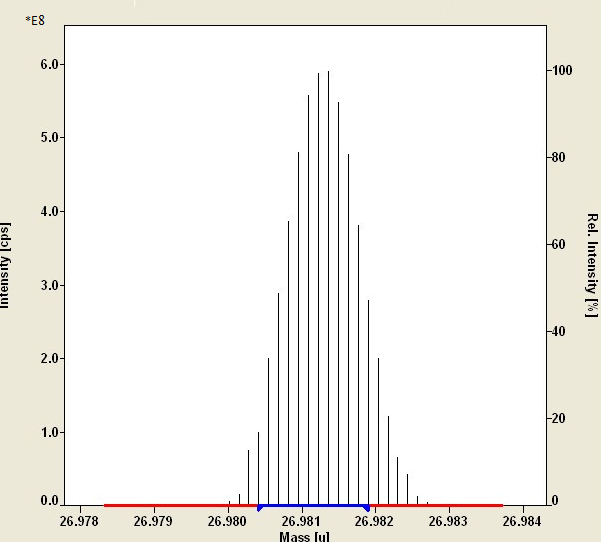


图2 高分辨下基体Al的信号峰

产生辉光放电的工作条件通常有放电电压、放电电流及放电气体压力（或单位流量），这三个参数相互关联。ELEMENT GD型GDMS采用调节放电电流的方法，电压随着电流的变化而自行变化，在确定仪器条件时不需调节优化。

**3.5.1.1放电电流对RSF值测定的影响**

通常来说，放电电流愈大，样品的溅射率愈高，被测元素的灵敏度随着愈高，但电流太大易使阳极帽上的沉积物快速增加而导致短路现象发生，使辉光放电过程不能继续进行。此实验是考察在中分辨率下放电电流的变化对样品测定结果的影响，结果如图3所示：

图3 放电电流对RSF值的影响

由图3所示，各元素的RSF值随放电电流的变化方向和幅度都有明显变化，63Cu呈现明显的升高趋势，而48Ti、28Si、56Fe等都有明显的降低趋势。再结合基体的信号峰最终选择放电电流为60mA。

**3.5.1.2放电气体电流对RSF值测定的影响**

在辉光放电体系中放电气体压强或流量（离子源真空度）决定参与碰撞和电离的惰性气体原子的数目。一般来说，在固定的放电电压下，增大放电气体压强可以提高放电电流，进入质谱仪的离子束强度增大，被测离子的灵敏度随之增高；另一方面，要维持同样的放电电流，如果增大放电气体压强，则所需的放电电压就会下降。放电条件选择的原则是要最终获得有一定强度的、稳定的样品基体离子束强度，同时要注意过高的放电气体压强可能导致气体背景增大。结果表图42所示。



图4 放电气体流量对RSF值的影响

由图4所示，各元素的RSF值随放电气体流量的变化方向是一致的，只是变化的幅度有某些区别。因此放电气体流量对RSF影响是很显著的。

**3.5.1.3离子源样品冷却温度对RSF值测定的影响**

样品在辉光放电过程中温度会缓慢升高，采取制冷手段可以起到稳定样品表面温度的作用。在不同的GDMS 仪器上采用不同的冷却手段（如VG9000 采用液氮冷却，Element GD采用半导体制冷），主要考虑来自放电气体和吸附在离子源上的C、N 和O 等气体杂质易与基体离子形成复合分子离子对一些被测同位素产生质谱重叠干扰，冷却后能减少这些气体杂质分子在辉光放电中碰撞和电离的机会，从而降低干扰。结果如表2所示：

表2 离子源温度对RSF的影响



根据以上的讨论，最终选择GDMS的仪器参数如表2所示：

**3.5.2 预溅射过程**

由于被测样品的表面在保存和前处理的切割过程中不可避免的会被沾污，因此，必须对样品进行欲溅射。图5为23Na、28Si、 56Fe、63Cu、66Zn含量随溅射时间的变化曲线。由图中可以看出在15min之后各待测元素的含量趋于稳定，不再随溅射时间的增加而出现明显的下降趋势。因此在溅射15min时可以结束对样品预溅射，以确保被测杂质元素信号的准确和稳定。

图5 溅射时间对待测元素分析结果的影响

**3.5.3 质谱干扰**

普通的四极杆辉光放电质谱仪只具有单位分辨的本领，因此无法解决由于基体气体引起的各种质谱干扰问题。辉光放电质谱中质谱干扰由放电气体( 如氩气) 、残留的空气( 氮气、氧气等) 以及溅射出的样品原子等相互碰撞、相互作用而形成, 同量异位素干扰；多原子离子干扰；多电荷离子干扰。

在GDMS 中最主要的干扰是多原子离子产生的谱线重叠干扰。多原子离子的来源有多种, 主要有等离子体气体( 氩气) 形成的多原子离子( 如40 Ar22+对80Se+ 的干扰)；污染或残留气体形成的多原子离子( 如14N2+ 对28 Si+ 的干扰)；样品中的原子间形成的多原子离子( 如58 Ni2+ 对116 Sn+ 的干扰) ；它们相互间结合形成的多原子离子( 如27Al36Ar对63Cu 、27Al40 Ar 对67Zn 的干扰)。

对于GDMS 中多原子离子等干扰是确实存在的，为了得到准确的分析结果, 必须将影响准确测定离子强度的干扰排除或者减小到最低的程度。可以通过以下方法：

(1)选择合适的质量数和选择合适的分辨率。

例如63Cu和27Al36Ar在低分辩率的情况下是分不开，但是在中分辨率R=4000时，如图6所示63Cu和27Al36Ar已经很明显的分开，可以实现63Cu的准确测定。

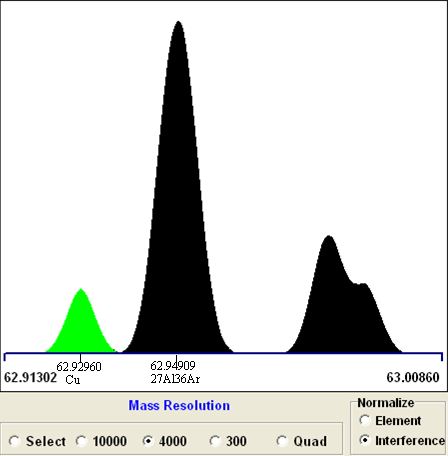


图6 63Cu和27Al36Ar峰图

67Zn和27Al40Ar在低分辩率的情况下是分不开，但是在高分辨率R=10000时，如图7所示67Zn和27Al40Ar已经很明显的分开，可以实现67Zn的准确测定。

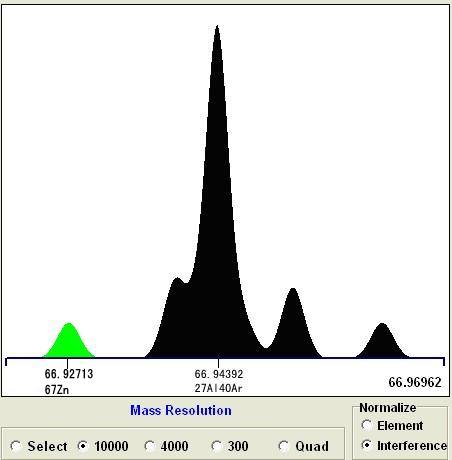
****

图7 67Zn和27Al40Ar的峰图

同样各元素所选择的质量数和分辩率如表3所示：

表3各元素所选择的质量数和分辩率

| **测定**  **元素** | **质量数** | **测定**  **元素** | **质量数** | **测定**  **元素** | **质量数** |
| --- | --- | --- | --- | --- | --- |
| **Li** | 7 | **As** | 75 | **Sm** | 147 |
| **Be** | 9 | **Se** | 82 | **Eu** | 151 |
| **B** | 11 | **Br** | 79 | **Gd** | 157 |
| **F** | 19 | **Rb** | 85 | **Tb** | 159 |
| **Na** | 23 | **Sr** | 88 | **Dy** | 163 |
| **Mg** | 24 | **Y** | 89 | **Ho** | 165 |
| **Al** | 27 | **Zr** | 92 | **Er** | 166 |
| **Si** | 28 | **Nb** | 93 | **Tm** | 169 |
| **P** | 31 | **Mo** | 95 | **Yb** | 172 |
| **S** | 32 | **Ru** | 101 | **Lu** | 175 |
| **Cl** | 35 | **Rh** | 103 | **Hf** | 178 |
| **K** | 39 | **Pd** | 106 | **Ta** | 181 |
| **Ca** | 44 | **Ag** | 109 | **W** | 184 |
| **Sc** | 45 | **Cd** | 114 | **Re** | 187 |
| **Ti** | 47 | **In** | 115 | **Os** | 190 |
| **V** | 51 | **Sn** | 118 | **Ir** | 191 |
| **Cr** | 52 | **Sb** | 123 | **Pt** | 195 |
| **Mn** | 55 | **Te** | 128 | **Au** | 197 |
| **Fe** | 56 | **I** | 127 | **Hg** | 200 |
| **Co** | 59 | **Cs** | 133 | **Tl** | 205 |
| **Ni** | 60 | **Ba** | 138 | **Pb** | 208 |
| **Cu** | 63 | **La** | 139 | **Bi** | 209 |
| **Zn** | 64,67 | **Ce** | 140 | **Th** | 232 |
| **Ga** | 71 | **Pr** | 141 | **U** | 238 |
| **Ge** | 72 | **Nd** | 146 | **-** |  |

(2)待测元素的信号峰和干扰峰判断。

在GDMS 中最主要的干扰是多原子离子产生的谱线重叠干扰。以纯铝基体中27Al36Ar对63Cu 、27Al1H 对28Si 的干扰为例。在选择待测元素的信号峰的同时将多原子离子的峰也同时选择判断，这样就能提高对待测元素信号峰判断的准确性。如图8、9所示：

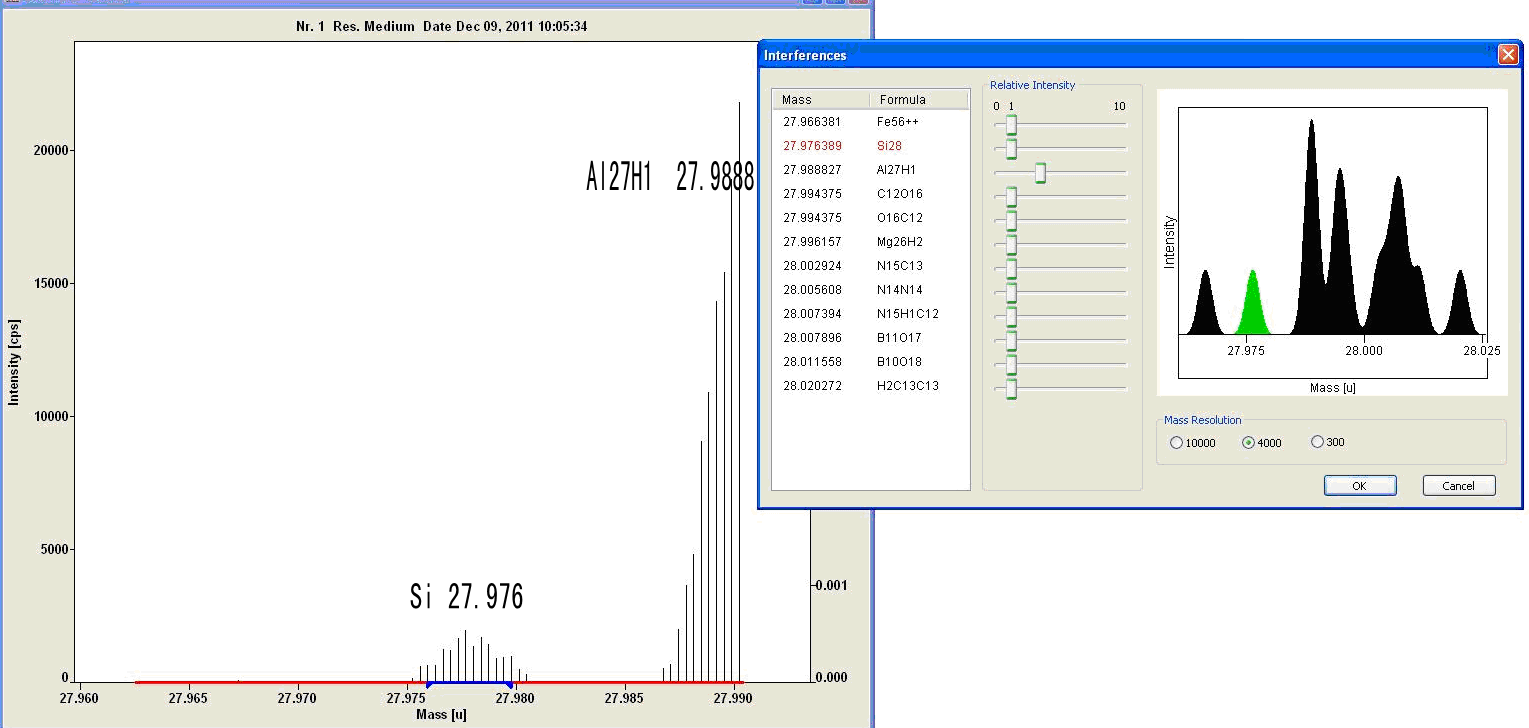
****

图8 27Al1H 对28Si 的干扰

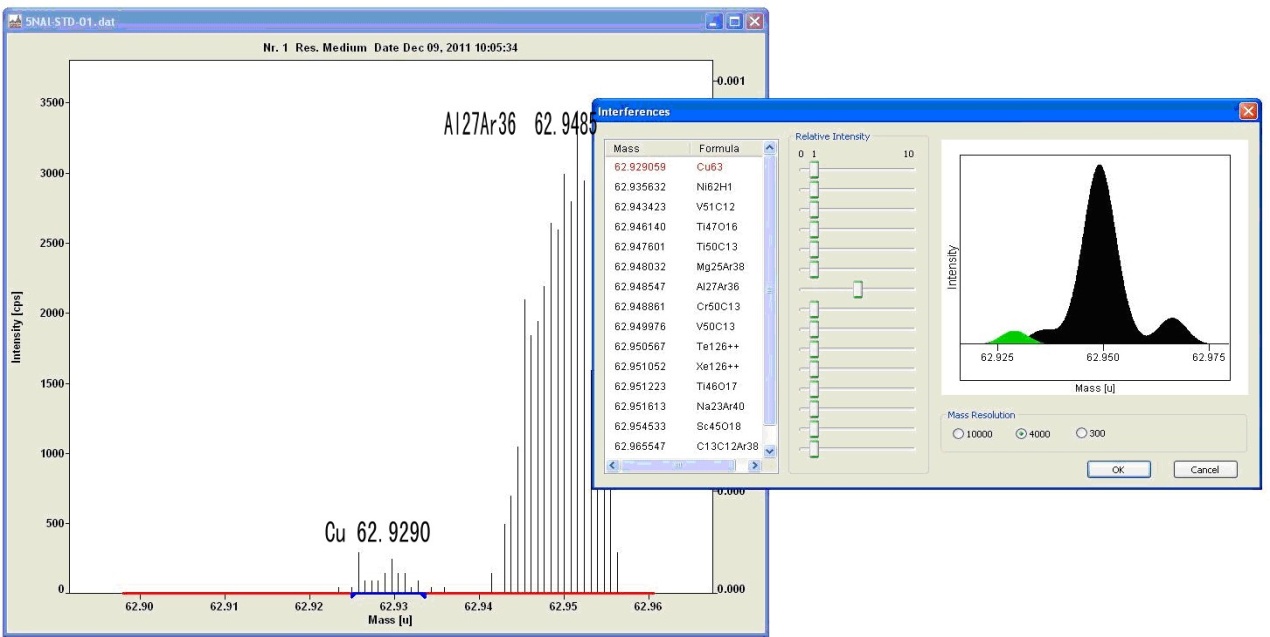
****

图9 27Al36Ar对63Cu

**3.5.4准确性**

本标准是利用杂质均匀性良好的美国加联仪器Well Group Scientific纯铝标样进行测定，以此验证方法的准确性，从表4结果可以看出大部分元素的准确性良好，证明利用GDMS可以准确测定纯铝中杂质。

表4 待测元素标准值与测定值的对比

| **测定**  **元素** | **标准值/mg/kg** | **测定值/mg/kg** | **测定**  **元素** | **标准值/mg/kg** | **测定值/ mg/kg** | **测定**  **元素** | **标准值/mg/kg** | **测定值/mg/kg** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|
|  |
| Li | - | - | As | 0.173 | 0.555 | Sm | 0.020 | <0.005 |
| Be | <0.05 | <0.005 | Se | - | - | Eu | - | - |
| B | - | - | Br | <0.005 | 0.40 | Gd | - | - |
| F | - | - | Rb | <0.01 | 0.006 | Tb | 0.007 | <0.005 |
| Na | <0.8 | 0.265 | Sr | <0.1 | <0.005 | Dy | - | - |
| Mg | 2.360 | 3.294 | Y | - | - | Ho | - | - |
| Al | - | - | Zr | 1.170 | 1.044 | Er | - | - |
| Si | 3.000 | 3.747 | Nb | 0.192 | 0.119 | Tm | - | - |
| P | 17.700 | 13.732 | Mo | 0.380 | 0.309 | Yb | - | - |
| S | 0.075 | 0.015 | Ru | - | - | Lu | - | - |
| Cl | -- | - | Rh | - | - | Hf | 0.010 | 0.018 |
| K | <0.1 | 0.290 | Pd | - | - | Ta | <0.003 | 0.097 |
| Ca | <0.2 | 0.132 | Ag | <0.01 | 0.086 | W | 0.002 | 0.062 |
| Sc | 0.062 | 0.043 | Cd | 0.013 | 0.044 | Re | - | - |
| Ti | 0.310 | 0.174 | In | <0.001 | 0.022 | Os | - | - |
| V | 0.070 | 0.016 | Sn | <1 | 0.059 | Ir | <0.003 | 0.073 |
| Cr | 0.050 | 0.049 | Sb | 0.081 | 0.153 | Pt | - | - |
| Mn | <0.3 | 0.064 | Te | - | - | Au | - | - |
| Fe | 19.70 | 19.49 | I | - | - | Hg | <0.002 | 0.028 |
| Co | 0.001 | 0.020 | Cs | <0.001 | <0.005 | Tl | - | - |
| Ni | 0.050 | 0.061 | Ba | <0.2 | <0.005 | Pb | 0.185 | 0.121 |
| Cu | 2.520 | 2.875 | La | 0.086 | 0.386 | Bi | 0.047 | 0.054 |
| Zn | 0.530 | 0.273 | Ce | 0.375 | 0.357 | Th | 0.063 | 0.039 |
| Ga | 0.023 | 0.059 | Pr | - | - | U | 0.095 | 0.027 |
| Ge | - | - | Nd | - | - | - | - |  |

**3.6 精密度**

**3.6.1 起草单位精密度数据**

依据以上实验条件的讨论,起草单位对4N和5N两个水平纯铝样品按照最佳实验条件进行分析，待数据稳定后，采集最后七次数据，计算平均值和相对标准偏差RSD如表5～6所示：

表5 5N铝样品测试数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0.001 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | <0.005 | - |
| Be | 0 | 0.001 | 0.001 | 0 | 0.001 | 0.001 | 0.001 | <0.005 | - |
| B | 0.001 | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 | 0.002 | <0.005 | - |
| F | 0.4 | 0.398 | 0.399 | 0.402 | 0.401 | 0.401 | 0.401 | 0.4 | 0.35 |
| Na | 0.082 | 0.079 | 0.077 | 0.067 | 0.072 | 0.081 | 0.072 | 0.076 | 7.07 |
| Mg | 0.111 | 0.11 | 0.106 | 0.111 | 0.108 | 0.112 | 0.11 | 0.11 | 1.82 |
| Si | 1.01 | 1.02 | 1.01 | 1.02 | 1.01 | 1.01 | 1.01 | 1.013 | 0.48 |
| P | 0.84 | 0.854 | 0.848 | 0.863 | 0.84 | 0.869 | 0.85 | 0.852 | 1.29 |
| S | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Cl | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| K | 0.048 | 0.048 | 0.048 | 0.048 | 0.053 | 0.05 | 0.051 | 0.049 | 4.25 |
| Ca | 0.079 | 0.068 | 0.082 | 0.087 | 0.057 | 0.062 | 0.077 | 0.073 | 15.3 |
| Sc | 0.018 | 0.018 | 0.02 | 0.015 | 0.021 | 0.016 | 0.015 | 0.018 | 14.12 |
| Ti | 0.081 | 0.098 | 0.097 | 0.116 | 0.1 | 0.101 | 0.105 | 0.1 | 10.47 |
| V | 0.128 | 0.141 | 0.134 | 0.135 | 0.135 | 0.131 | 0.132 | 0.134 | 3.24 |
| Cr | 0.061 | 0.061 | 0.061 | 0.06 | 0.061 | 0.061 | 0.061 | 0.061 | 0.63 |
| Mn | 0.039 | 0.044 | 0.04 | 0.046 | 0.046 | 0.041 | 0.045 | 0.043 | 6.6 |
| Fe | 0.626 | 0.631 | 0.629 | 0.631 | 0.64 | 0.619 | 0.637 | 0.631 | 1.11 |
| Co | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.8 |
| Ni | 0.243 | 0.269 | 0.236 | 0.21 | 0.23 | 0.234 | 0.237 | 0.237 | 7.41 |
| Cu | 1.216 | 1.129 | 1.15 | 1.17 | 1.21 | 1.168 | 1.184 | 1.175 | 2.63 |
| Zn | 0.421 | 0.383 | 0.372 | 0.363 | 0.367 | 0.377 | 0.424 | 0.387 | 6.59 |
| Ga | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |  |
| Ge | 0.017 | 0.011 | 0.015 | 0.016 | 0.019 | 0.015 | 0.016 | 0.016 | 13.83 |
| As | 0.078 | 0.061 | 0.098 | 0.087 | 0.083 | 0.058 | 0.072 | 0.077 | 18.63 |
| Se | 0.469 | 0.434 | 0.439 | 0.423 | 0.438 | 0.424 | 0.461 | 0.441 | 3.96 |
| Br | 0.273 | 0.263 | 0.24 | 0.198 | 0.258 | 0.268 | 0.275 | 0.253 | 10.68 |
| Rb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Y | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Zr | 0.033 | 0.026 | 0.026 | 0.03 | 0.028 | 0.028 | 0.026 | 0.028 | 8.81 |
| Nb | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 4.74 |
| Mo | 0.01 | 0.012 | 0.01 | 0.012 | 0.01 | 0.012 | 0.011 | 0.011 | 8.94 |
| Ru | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | #VALUE! |
| Rh | 0.13 | 0.132 | 0.13 | 0.13 | 0.131 | 0.131 | 0.13 | 0.131 | 0.54 |
| Pd | 0.012 | 0.013 | 0.015 | 0.013 | 0.01 | 0.012 | 0.014 | 0.013 | 12.53 |
| Ag | 0.033 | 0.034 | 0.033 | 0.034 | 0.031 | 0.03 | 0.034 | 0.033 | 5.1 |
| Cd | 0.054 | 0.059 | 0.051 | 0.061 | 0.052 | 0.057 | 0.061 | 0.056 | 7.34 |
| In | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sn | 0.022 | 0.021 | 0.029 | 0.03 | 0.033 | 0.033 | 0.025 | 0.028 | 18.05 |
| Sb | 0.029 | 0.026 | 0.027 | 0.026 | 0.026 | 0.028 | 0.026 | 0.027 | 3.78 |
| Te | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| I | 0.013 | 0.008 | 0.013 | 0.011 | 0.007 | 0.01 | 0.012 | 0.01 | 22.99 |
| Cs | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ba | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| La | 0.006 | 0.007 | 0.006 | 0.008 | 0.006 | 0.007 | 0.006 | 0.007 | 10.91 |
| Ce | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Nd | 0.011 | 0.011 | 0.011 | 0.011 | 0.007 | 0.011 | 0.009 | 0.01 | 16.12 |
| Sm | 0.005 | 0.005 | 0.005 | 0.004 | 0.005 | 0.003 | 0.005 | <0.005 | - |
| Eu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Gd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Dy | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ho | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Er | 0.014 | 0.015 | 0.017 | 0.017 | 0.012 | 0.012 | 0.013 | 0.014 | 14.48 |
| Tm | 0.007 | 0.008 | 0.009 | 0.008 | 0.008 | 0.009 | 0.008 | 0.008 | 6.58 |
| Yb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Lu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Hf | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ta | 0.129 | 0.129 | 0.127 | 0.134 | 0.132 | 0.13 | 0.129 | 0.13 | 1.65 |
| W | 0.025 | 0.024 | 0.023 | 0.024 | 0.022 | 0.022 | 0.023 | 0.023 | 4.07 |
| Re | 0.096 | 0.077 | 0.082 | 0.075 | 0.073 | 0.075 | 0.065 | 0.077 | 12.13 |
| Os | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ir | 0.061 | 0.061 | 0.06 | 0.06 | 0.062 | 0.06 | 0.056 | 0.06 | 3.12 |
| Pt | 0.048 | 0.052 | 0.049 | 0.046 | 0.043 | 0.056 | 0.048 | 0.049 | 8.23 |
| Au | 0.08 | 0.078 | 0.078 | 0.078 | 0.08 | 0.075 | 0.078 | 0.078 | 2.06 |
| Hg | 0.016 | 0.013 | 0.013 | 0.014 | 0.013 | 0.012 | 0.013 | 0.013 | 8.6 |
| Tl | 0.016 | 0.012 | 0.018 | 0.015 | 0.018 | 0.014 | 0.016 | 0.016 | 13.53 |
| Pb | 0.006 | 0.006 | 0.006 | 0.007 | 0.007 | 0.006 | 0.007 | 0.007 | 8.89 |
| Bi | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Th | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| U | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |

表5 4N铝样品测试数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0.002 |  |  |  |  |  |  | <0.005 | - |
| Be |  |  | 0.006 | 0.006 |  |  |  | 0.006 | - |
| B |  |  |  |  |  |  |  | <0.005 | - |
| F | 0.880 | 0.891 | 0.880 | 0.877 | 0.897 | 0.886 | 0.879 | 0.88 | 0.81 |
| Na | 0.327 | 0.304 | 0.315 | 0.315 | 0.309 | 0.402 | 0.291 | 0.32 | 11 |
| Mg | 0.950 | 0.958 | 0.982 | 0.958 | 0.919 | 0.928 | 0.837 | 0.93 | 5.1 |
| Si | 6.745 | 6.430 | 6.506 | 6.544 | 6.780 | 6.521 | 6.569 | 6.59 | 1.9 |
| P | 0.348 | 0.354 | 0.351 | 0.350 | 0.350 | 0.352 | 0.350 | 0.35 | 0.53 |
| S | 0.032 | 0.032 | 0.037 | 0.045 | 0.049 | 0.032 | 0.033 | <0.05 | - |
| Cl |  |  |  |  |  |  |  | <0.05 | - |
| K | 0.139 | 0.172 | 0.168 | 0.193 | 0.171 | 0.100 | 0.138 | 0.15 | 20 |
| Ca | 0.064 | 0.062 | 0.062 | 0.059 | 0.047 | 0.061 | 0.061 | 0.059 | 9.3 |
| Sc | 0.011 | 0.009 | 0.010 | 0.010 | 0.010 | 0.010 | 0.009 | 0.010 | 6.6 |
| Ti | 0.404 | 0.423 | 0.428 | 0.476 | 0.422 | 0.442 | 0.456 | 0.44 | 5.6 |
| V | 0.733 | 0.761 | 0.742 | 0.773 | 0.738 | 0.774 | 0.768 | 0.76 | 2.3 |
| Cr | 1.175 | 1.121 | 1.142 | 1.131 | 1.034 | 1.012 | 1.072 | 1.09 | 5.5 |
| Mn | 4.572 | 4.620 | 4.573 | 4.611 | 4.593 | 4.638 | 4.750 | 4.62 | 1.3 |
| Fe | 4.126 | 4.110 | 4.090 | 4.116 | 4.108 | 4.132 | 4.151 | 4.12 | 0.47 |
| Co | 4.124 | 4.110 | 4.119 | 4.125 | 4.119 | 4.118 | 4.107 | 4.12 | 0.16 |
| Ni | 0.010 | 0.007 | 0.009 | 0.009 | 0.008 | 0.010 | 0.008 | 0.009 | 12 |
| Cu | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.051 | 0.050 | 0.052 | 1.7 |
| Zn | 2.013 | 2.038 | 2.035 | 2.054 | 2.018 | 2.002 | 2.120 | 2.04 | 1.9 |
| Ga | 7.020 | 7.021 | 7.020 | 7.020 | 7.020 | 7.021 | 7.022 | 7.02 | 0.012 |
| Ge | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| As | 0.183 | 0.178 | 0.182 | 0.185 | 0.183 | 0.179 | 0.176 | 0.18 | 1.8 |
| Se | 0.187 | 0.178 | 0.170 | 0.180 | 0.160 | 0.170 | 0.174 | 0.17 | 4.9 |
| Br | 0.703 | 0.742 | 0.812 | 0.790 | 0.742 | 0.735 | 0.724 | 0.750 | 5.1 |
| Rb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Y | 0.013 | 0.007 | 0.012 | 0.015 | 0.015 | 0.009 | 0.014 | 0.012 | 26 |
| Zr | 0.431 | 0.435 | 0.421 | 0.398 | 0.440 | 0.394 | 0.409 | 0.418 | 4.4 |
| Nb | 0.010 | 0.007 | 0.009 | 0.009 | 0.011 | 0.008 | 0.012 | 0.009 | 19 |
| Mo | 0.501 | 0.507 | 0.504 | 0.503 | 0.505 | 0.504 | 0.501 | 0.503 | 0.41 |
| Ru | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Rh | 0.048 | 0.040 | 0.043 | 0.042 | 0.043 | 0.042 | 0.045 | 0.043 | 5.8 |
| Pd | 0.013 | 0.013 | 0.012 | 0.010 | 0.014 | 0.014 | 0.012 | 0.012 | 12 |
| Ag | 0.009 | 0.010 | 0.010 | 0.011 | 0.013 | 0.009 | 0.010 | 0.010 | 10 |
| Cd | 0.058 | 0.065 | 0.059 | 0.055 | 0.052 | 0.065 | 0.061 | 0.059 | 8.3 |
| In | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sn | 0.017 | 0.013 | 0.014 | 0.013 | 0.013 | 0.018 | 0.016 | 0.015 | 15 |
| Sb | 0.019 | 0.020 | 0.020 | 0.021 | 0.020 | 0.024 | 0.019 | 0.020 | 8.9 |
| Te | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| I | 0.026 | 0.028 | 0.024 | 0.026 | 0.028 | 0.026 | 0.023 | 0.026 | 6.8 |
| Cs | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ba | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| La | 0.097 | 0.100 | 0.101 | 0.107 | 0.135 | 0.133 | 0.121 | 0.114 | 14 |
| Ce | 0.110 | 0.091 | 0.097 | 0.098 | 0.095 | 0.095 | 0.109 | 0.099 | 7.4 |
| Pr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Nd | 0.029 | 0.036 | 0.029 | 0.032 | 0.035 | 0.029 | 0.035 | 0.032 | 9.8 |
| Sm | 0.014 | 0.017 | 0.016 | 0.016 | 0.014 | 0.014 | 0.012 | 0.015 | 12 |
| Eu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Gd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Dy | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ho | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Er | 0.027 | 0.027 | 0.027 | 0.026 | 0.027 | 0.027 | 0.027 | 0.027 | 1.5 |
| Tm | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Yb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Lu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Hf | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ta | 0.192 | 0.188 | 0.191 | 0.192 | 0.183 | 0.192 | 0.191 | 0.190 | 1.8 |
| W | 0.070 | 0.053 | 0.061 | 0.060 | 0.058 | 0.068 | 0.078 | 0.064 | 13 |
| Re | 0.249 | 0.203 | 0.211 | 0.181 | 0.176 | 0.213 | 0.187 | 0.203 | 12 |
| Os | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 | 0.010 | 0.009 | 5.3 |
| Ir | 0.214 | 0.189 | 0.198 | 0.192 | 0.195 | 0.221 | 0.252 | 0.209 | 11 |
| Pt | 0.033 | 0.033 | 0.032 | 0.024 | 0.033 | 0.035 | 0.037 | 0.033 | 12 |
| Au | 0.214 | 0.209 | 0.209 | 0.202 | 0.213 | 0.190 | 0.190 | 0.204 | 5.0 |
| Hg | 0.035 | 0.036 | 0.039 | 0.036 | 0.039 | 0.040 | 0.038 | 0.038 | 5.2 |
| Tl | 0.013 | 0.014 | 0.014 | 0.015 | 0.012 | 0.013 | 0.017 | 0.014 | 11 |
| Pb | 0.010 | 0.010 | 0.011 | 0.011 | 0.009 | 0.011 | 0.010 | 0.010 | 9.4 |
| Bi | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Th | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| U | 0.039 | 0.042 | 0.040 | 0.040 | 0.040 | 0.039 | 0.040 | 0.040 | 2.3 |

**3.6.2验证单位精密度数据**

为了考察本方法的允许差，在国内选择4家实验室，按照起草单位制定的实验方案进行了协同试验，其中一验单位新疆众合有限公司并对条件实验进行验证，对两个水平的纯铝样品进行分析测定，并统计计算平均值和相对标准偏差RSD，结果见表6~9所示。

表6 新疆众合5N铝样品测定数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0 | 0 | 0.0025 | 0 | 0 | 0.0028 | 0.0084 | 0.002 | 158.60% |
| Be | 0.0114 | 0 | 0 | 0 | 0 | 0.0063 | 0 | 0.0025 | 180.40% |
| B | 0.0268 | 0.0136 | 0 | 0.0352 | 0.0389 | 0.0292 | 0.0376 | 0.0259 | 55.20% |
| F |  |  |  |  |  |  |  |  |  |
| Na | 0.0139 | 0.016 | 0.022 | 0.0076 | 0.0096 | 0.0145 | 0.0137 | 0.0139 | 33.30% |
| Mg | 0.081 | 0.0645 | 0.0738 | 0.0833 | 0.078 | 0.108 | 0.0714 | 0.08 | 17.30% |
| Si | 0.6154 | 0.8113 | 0.8786 | 0.9311 | 0.8415 | 0.7224 | 0.6619 | 0.7803 | 15.00% |
| P | 0.382 | 0.378 | 0.5972 | 0.5483 | 0.3213 | 0.4873 | 0.4951 | 0.4585 | 21.90% |
| S | 0.0241 | 0.0164 | 0.0393 | 0.0336 | 0.02709 | 0.01516 | 0.01941 | 0.025 | 36.00% |
| Cl | 0.1795 | 0.2755 | 0.3942 | 0.3277 | 0.3937 | 0.3053 | 0.3779 | 0.322 | 24.10% |
| K | 0.0209 | 0.0304 | 0.0145 | 0.0083 | 0.0111 | 0.0064 | 0.0066 | 0.014 | 63.10% |
| Ca | 0.048 | 0.0386 | 0.0531 | 0.0725 | 0.074 | 0.0358 | 0.0412 | 0.0519 | 30.30% |
| Sc | 0.0134 | 0.0109 | 0.0291 | 0.015 | 0.0145 | 0.0178 | 0.0287 | 0.0185 | 40.10% |
| Ti | 0.1559 | 0.1892 | 0.2345 | 0.2545 | 0.1806 | 0.163 | 0.1648 | 0.1918 | 19.90% |
| V | 0.2187 | 0.239 | 0.2107 | 0.2484 | 0.3439 | 0.3593 | 0.2022 | 0.2603 | 24.80% |
| Cr | 0.0332 | 0.0322 | 0.0348 | 0.0526 | 0.0398 | 0.0398 | 0.046 | 0.0398 | 18.60% |
| Mn | 0.0463 | 0.0592 | 0.0341 | 0.0659 | 0.0558 | 0.0327 | 0.0411 | 0.0479 | 26.80% |
| Fe | 0.535 | 0.432 | 0.4289 | 0.5273 | 0.6406 | 0.483 | 0.4695 | 0.5023 | 14.70% |
| Co | 0 | 0 | 0.0046 | 0 | 0.0012 | 0 | 0 | 0.0008 | 207.80% |
| Ni | 0.2429 | 0.1523 | 0.2624 | 0.216 | 0.2375 | 0.1455 | 0.13 | 0.1981 | 27.30% |
| Cu | 0.6068 | 0.704 | 0.5433 | 0.534 | 0.6028 | 0.6172 | 0.5096 | 0.5882 | 11.20% |
| Zn | 1.0105 | 0.896 | 0.8435 | 1.0932 | 0.8929 | 0.9271 | 0.8225 | 0.9265 | 10.30% |
| Ga | 0.0096 | 0.029 | 0.0099 | 0.0264 | 0.0153 | 0.00735 | 0.0159 | 0.0162 | 52.30% |
| Ge | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| As | 0 | 0 | 0 | 0 | 0.0159 | 0 | 0 | 0.0023 | - |
| Se | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| Br | 0.0279 | 0.0047 | 0 | 0.0302 | 0.0049 | 0.01 | 0 | 0.0111 | 114.80% |
| Rb | 0.0063 | 0.0032 | 0.0024 | 0.0029 | 0 | 0.0014 | 0.0024 | 0.0027 | 72.70% |
| Sr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Y | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Zr | 0.0054 | 0.0165 | 0.0267 | 0.0253 | 0.0234 | 0 | 0.0183 | 0.0165 | 61.90% |
| Nb | 0 | 0 | 0 | 0 | 0 | 0 | 0.0017 | 0.0002 | 264.60% |
| Mo | 0 | 0.0222 | 0 | 0 | 0.0037 | 0 | 0 | 0.0037 | 223.60% |
| Ru | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Rh | 0 | 0 | 0.0092 | 0 | 0 | 0 | 0 | 0.0013 | 264.60% |
| Pd | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Ag | 0 | 0 | 0.0086 | 0 | 0 | 0 | 0 | 0.0012 | 264.60% |
| Cd | 0.0094 | 0.038 | 0.0092 | 0 | 0 | 0 | 0.0105 | 0.0096 | 140.20% |
| In | 0.0166 | 0.016 | 0.0078 | 0.0064 | 0.0157 | 0.0188 | 0.0102 | 0.0131 | 37.10% |
| Sn | 0 | 0 | 0 | 0 | 0.0438 | 0 | 0 | 0.0063 | 264.60% |
| Sb |  |  |  |  |  |  |  |  |  |
| Te | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Cs | 0 | 0.0023 | 0 | 0 | 0 | 0 | 0 | 0.0003 | 264.60% |
| Ba | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| La | 0.0008 | 0.0017 | 0.0028 | 0.0008 | 0.0022 | 0.0014 | 0.0009 | 0.0015 | 50.90% |
| Ce | 0.0024 | 0.0043 | 0.0084 | 0.01 | 0 | 0.0024 | 0.0089 | 0.0052 | 74.70% |
| Pr | 0 | 0 | 0.0015 | 0 | 0.0017 | 0 | 0 | 0.0005 | 171.20% |
| Nd | 0.0096 | 0 | 0.0065 | 0.0031 | 0.0315 | 0.0073 | 0.0074 | 0.0093 | 110.00% |
| Sm | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Eu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Gd | 0.0017 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0002 | 264.60% |
| Tb | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Dy | 0.0039 | 0.0061 | 0.006 | 0 | 0 | 0.0067 | 0.0023 | 0.0036 | 80.30% |
| Ho | 0.0015 | 0.0026 | 0.0015 | 0.001 | 0 | 0.0006 | 0.0029 | 0.0014 | 71.90% |
| Er | 0.0028 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0004 | 264.60% |
| Tm | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Yb | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Lu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Hf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| Ta | 0.0427 | 0.0265 | 0.0607 | 0.0226 | 0.037 | 0.0284 | 0.052 | 0.0386 | 36.60% |
| W | 0.0099 | 0 | 0.0033 | 0 | 0.0072 | 0.0037 | 0 | 0.0034 | 113.40% |
| Re | 0 | 0 | 0 | 0 | 0.0011 | 0 | 0 | 0.0002 | 264.60% |
| Os | 0 | 0.0029 | 0.0028 | 0.0107 | 0 | 0.0063 | 0 | 0.0032 | 123.90% |
| Ir | 0.0014 | 0 | 0 | 0.0027 | 0 | 0 | 0.0064 | 0.0015 | 159.80% |
| Pt | 0 | 0 | 0.0188 | 0 | 0.0051 | 0 | 0 | 0.0034 | 206.40% |
| Au |  |  |  |  |  |  |  |  |  |
| Hg | 0.0213 | 0.0088 | 0 | 0.0123 | 0.0139 | 0 | 0.0196 | 0.0108 | 78.70% |
| Tl | 0.0099 | 0.0061 | 0.006 | 0.0076 | 0 | 0.0045 | 0.0023 | 0.0052 | 63.40% |
| Pb | 0.0092 | 0.021 | 0.0112 | 0.0142 | 0.0342 | 0.0168 | 0.0106 | 0.0167 | 52.00% |
| Bi | 0 | 0.001 | 0.0044 | 0 | 0.0028 | 0 | 0.0017 | 0.0014 | 119.30% |
| Th | 0.0006 | 0 | 0 | 0.0017 | 0.0019 | 0.0007 | 0.0013 | 0.0009 | 86.80% |
| U | 0.0019 | 0.0033 | 0.0019 | 0.0012 | 0 | 0.0036 | 0.0007 | 0.0018 | 72.90% |

表7 昆明冶金研究院5N铝样品测定数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0.0052 | 0.0051 | 0.0037 | 0.0043 | 0.0066 | 0.0068 | 0.0031 | 0.005 | 28.1 |
| Be | 0.0025 | 0.0035 | 0.0066 | 0.0027 | 0.0063 | 0.0072 | 0.0061 | 0.005 | 40.51 |
| B | 0.0183 | 0.0149 | 0.0089 | 0.0176 | 0.0191 | 0.0156 | 0.0104 | 0.015 | 26.32 |
| F | 0.0279 | 0.0325 | 0.0431 | 0.0216 | 0.0211 | 0.0313 | 0.0225 | 0.029 | 27.7 |
| Na | 0.0028 | 0.0029 | 0.009 | 0.004 | 0.0055 | 0.0082 | 0.0062 | 0.006 | 44.62 |
| Mg | 0.0117 | 0.0384 | 0.0265 | 0.0242 | 0.0148 | 0.0494 | 0.0114 | 0.025 | 57.13 |
| Si | 1.1267 | 0.6931 | 0.603 | 0.4943 | 0.45 | 0.4464 | 0.4237 | 0.61 | 41.26 |
| P | 0.1257 | 0.1395 | 0.1478 | 0.1764 | 0.1676 | 0.1604 | 0.187 | 0.16 | 13.61 |
| S | 0.0732 | 0.0465 | 0.0819 | 0.046 | 0.0475 | 0.0603 | 0.0341 | 0.056 | 30.48 |
| Cl | 0.0259 | 0.0248 | 0.0242 | 0.0212 | 0.0199 | 0.021 | 0.0211 | 0.023 | 10.35 |
| K | 0.0712 | 0.028 | 0.0663 | 0.02 | 0.043 | 0.0363 | 0.045 | 0.044 | 42.57 |
| Ca | 0.0195 | 0.0125 | 0.049 | 0.0135 | 0.0434 | 0.0239 | 0.0248 | 0.027 | 53.39 |
| Sc | 0.0025 | 0.0057 | 0.0085 | 0.0043 | 0.0033 | 0.0121 | 0.0078 | 0.006 | 53.52 |
| Ti | 0.0472 | 0.0654 | 0.0788 | 0.0688 | 0.0292 | 0.0636 | 0.0746 | 0.061 | 28.28 |
| V | 0.0246 | 0.0282 | 0.0319 | 0.0315 | 0.031 | 0.0267 | 0.0301 | 0.029 | 9.4 |
| Cr | 0.0218 | 0.025 | 0.0278 | 0.0107 | 0.0265 | 0.0263 | 0.0276 | 0.024 | 25.63 |
| Mn | 0.0058 | 0.0145 | 0.0133 | 0.0079 | 0.0074 | 0.0135 | 0.0078 | 0.01 | 35.73 |
| Fe | 0.1982 | 0.1112 | 0.1105 | 0.1131 | 0.1163 | 0.1 | 0.1146 | 0.12 | 27.06 |
| Co | 0.0256 | 0.0184 | 0.0225 | 0.0279 | 0.0232 | 0.0273 | 0.0265 | 0.024 | 13.7 |
| Ni | 0.1293 | 0.0928 | 0.0968 | 0.1556 | 0.0944 | 0.0932 | 0.0919 | 0.11 | 23.18 |
| Cu | 0.5867 | 0.4973 | 0.4991 | 0.585 | 0.1056 | 0.664 | 0.491 | 0.49 | 36.95 |
| Zn | 0.3259 | 0.3645 | 0.3801 | 0.301 | 0.5129 | 0.294 | 0.4232 | 0.37 | 20.8 |
| Ga | 0.0087 | 0.0024 | 0.002 | 0.0015 | 0.0089 | 0.0033 | 0.0038 | <0.005 | - |
| Ge | 0.0181 | 0.025 | 0.0154 | 0.0204 | 0.0231 | 0.0157 | 0.0258 | 0.021 | 20.88 |
| As | 0.0343 | 0.0385 | 0.0258 | 0.0297 | 0.0254 | 0.0196 | 0.0101 | 0.026 | 35.96 |
| Se | 0.2943 | 0.2395 | 0.387 | 0.2567 | 0.2239 | 0.2832 | 0.2157 | 0.27 | 21.59 |
| Br | 0.088 | 0.0683 | 0.0885 | 0.0746 | 0.0875 | 0.0871 | 0.0954 | 0.084 | 11.08 |
| Rb | 0.0005 | 0.0003 | 0 | 0 | 0.0011 | 0 | 0.0007 | <0.005 | - |
| Sr | 0.0067 | 0.0046 | 0.0011 | 0.0033 | 0.0085 | 0.0052 | 0.0024 | 0.005 | 55.93 |
| Y | 0.0079 | 0.0091 | 0.0041 | 0.0082 | 0.0103 | 0.0054 | 0.0037 | 0.007 | 36.83 |
| Zr | 0.0082 | 0.0051 | 0.0097 | 0.0069 | 0.0042 | 0.0013 | 0.0028 | 0.005 | 54.8 |
| Nb | 0.0033 | 0.0032 | 0.0052 | 0.0075 | 0.0056 | 0.0056 | 0.0062 | 0.005 | 29.44 |
| Mo | 0.0061 | 0.0054 | 0.0063 | 0.0013 | 0.0032 | 0.0057 | 0.0055 | 0.005 | 38.56 |
| Ru | 0.0007 | 0 | 0.0008 | 0 | 0.0007 | 0 | 0.0002 | <0.005 | - |
| Rh | 0.0141 | 0.0158 | 0.0294 | 0.0176 | 0.0132 | 0.013 | 0.0178 | 0.017 | 32.97 |
| Pd | 0.026 | 0.039 | 0.028 | 0.0352 | 0.031 | 0.0287 | 0.0371 | 0.032 | 15.52 |
| Ag | 0.0128 | 0.0109 | 0.0159 | 0.017 | 0.0156 | 0.0122 | 0.0148 | 0.014 | 15.7 |
| Cd | 0.067 | 0.072 | 0.025 | 0.0277 | 0.0256 | 0.028 | 0.0218 | 0.038 | 56.48 |
| In | 0.0012 | 0.0014 | 0.0084 | 0.0028 | 0.003 | 0.0029 | 0.0018 | <0.005 | - |
| Sn | 0.023 | 0.011 | 0.0654 | 0.0389 | 0.013 | 0.037 | 0.0258 | 0.031 | 61.1 |
| Sb | 0.023 | 0.019 | 0.052 | 0.025 | 0.018 | 0.015 | 0.014 | 0.024 | 55.18 |
| Te | 0.0007 | 0 | 0.0005 | 0.0004 | 0.003 | 0.0009 | 0.001 | <0.005 | - |
| I | 0.0074 | 0.0068 | 0.0082 | 0.0007 | 0.0065 | 0.0047 | 0.0032 | 0.005 | 49.63 |
| Cs | 0.0002 | 0.0002 | 0.0004 | 0.0001 | 0 | 0 | 0 | <0.005 | - |
| Ba | 0 | 0.0001 | 0 | 0 | 0 | 0 | 0 | <0.005 | - |
| La | 0 | 0.0003 | 0.0003 | 0.0043 | 0.0012 | 0.0003 | 0 | <0.005 | - |
| Ce | 0.0002 | 0.0003 | 0.0005 | 0.0002 | 0.0006 | 0.0004 | 0 | <0.005 | - |
| Pr | 0.0035 | 0.0022 | 0.0013 | 0.0024 | 0 | 0.0051 | 0.0044 | <0.005 | - |
| Nd | 0.019 | 0.0262 | 0.0083 | 0.0142 | 0.012 | 0.0154 | 0.0239 | 0.017 | 37.85 |
| Sm | 0.0181 | 0.0008 | 0.0154 | 0.0144 | 0.0273 | 0.0178 | 0.0098 | 0.015 | 55.01 |
| Eu | 0.0002 | 0.0001 | 0 | 0 | 0.0003 | 0 | 0 | <0.005 | - |
| Gd | 0.0029 | 0.0034 | 0.0009 | 0.0018 | 0.0029 | 0 | 0 | <0.005 | - |
| Tb | 0.0001 | 0 | 0.0006 | 0.0006 | 0 | 0 | 0 | <0.005 | - |
| Dy | 0.0017 | 0 | 0 | 0.0018 | 0.0022 | 0.0015 | 0 | <0.005 | - |
| Ho | 0.0074 | 0.0062 | 0.0019 | 0.0002 | 0 | 0.0002 | 0.0004 | <0.005 | - |
| Er | 0.0154 | 0.0157 | 0.0298 | 0.0218 | 0.0183 | 0.0144 | 0.0165 | 0.019 | 28.75 |
| Tm | 0 | 0 | 0 | 0 | 0.0003 | 0 | 0.0002 | <0.005 | - |
| Yb | 0.0011 | 0.0047 | 0 | 0 | 0.0047 | 0 | 0 | <0.005 | - |
| Lu | 0 | 0 | 0.005 | 0 | 0.0043 | 0.0055 | 0.0002 | <0.005 | - |
| Hf | 0.0147 | 0.0125 | 0.0122 | 0.0142 | 0.0157 | 0.019 | 0.0192 | 0.015 | 18.43 |
| Ta | 0.017 | 0.013 | 0.0103 | 0.0182 | 0.0129 | 0.0121 | 0.0233 | 0.015 | 29.5 |
| W | 0.0108 | 0.0458 | 0.0011 | 0.0307 | 0.0328 | 0.0234 | 0.0342 | 0.026 | 59.46 |
| Re | 0.0125 | 0.0098 | 0.0081 | 0.0273 | 0.034 | 0.0178 | 0.0189 | 0.018 | 51.62 |
| Os | 0 | 0 | 0 | 0 | 0 | 0 | 0.0019 | <0.005 | - |
| Ir | 0.0245 | 0.0698 | 0.0257 | 0.0342 | 0.0314 | 0.0469 | 0.0287 | 0.037 | 43.28 |
| Pt | 0.0357 | 0.0408 | 0.0389 | 0.0441 | 0.0544 | 0.0165 | 0.0239 | 0.036 | 34.85 |
| Au | 0 | 0.0005 | 0.0005 | 0 | 0 | 0.0016 | 0.0006 | <0.005 | - |
| Hg | 0 | 0.0039 | 0.0039 | 0 | 0.009 | 0.0087 | 0.0047 | <0.005 | - |
| Tl | 0.0381 | 0.034 | 0.0295 | 0.0237 | 0.0148 | 0.0414 | 0.0479 | 0.033 | 34.1 |
| Pb | 0.0043 | 0.0027 | 0.006 | 0.0033 | 0.0012 | 0.0024 | 0.0026 | <0.005 | - |
| Bi | 0 | 0.0041 | 0.0052 | 0.0006 | 0 | 0 | 0.0026 | <0.005 | - |
| Th | 0.0042 | 0.0018 | 0 | 0 | 0.0051 | 0 | 0 | <0.005 | - |
| U | 0 | 0.0002 | 0 | 0.0002 | 0.0002 | 0.0002 | 0 | <0.005 | - |

表8 深圳万泽中南5N铝样品测定数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0 | 0 | 0.006 | 0.0008 | 0.0055 | 0.0005 | 0 | <0.005 | - |
| Be | 0.0026 | 0.0221 | 0.0187 | 0.0081 | 0.011 | 0.0248 | 0 | 0.013 | 67.62 |
| B | 0.1776 | 0.2191 | 0.1306 | 0.1716 | 0.2258 | 0.3329 | 0.3354 | 0.23 | 34.89 |
| F | 0.2586 | 0.2381 | 0.2423 | 0.2102 | 0.188 | 0.3217 | 0.2813 | 0.25 | 17.85 |
| Na | 0.0302 | 0.0302 | 0.0296 | 0.0232 | 0.0343 | 0.0245 | 0.0288 | 0.029 | 13.09 |
| Mg | 0.0806 | 0.0892 | 0.0945 | 0.0633 | 0.0877 | 0.0652 | 0.0659 | 0.078 | 16.74 |
| Si | 1.6219 | 1.7116 | 1.6455 | 1.6114 | 1.5669 | 1.694 | 1.6801 | 1.65 | 3.11 |
| P | 0.8563 | 0.8094 | 0.6923 | 0.7057 | 0.8179 | 0.871 | 0.7546 | 0.79 | 8.98 |
| S | 1.133 | 0.9869 | 0.8175 | 0.7898 | 0.8041 | 0.8892 | 0.9744 | 0.91 | 13.73 |
| Cl | 0.3174 | 0.2107 | 0.1971 | 0.1398 | 0.119 | 0.135 | 0.1315 | 0.18 | 39.46 |
| K | 0.0294 | 0.0157 | 0.02 | 0.0117 | 0.0118 | 0.0171 | 0.0161 | 0.017 | 34.74 |
| Ca | 0 | 0 | 0.0032 | 0.0002 | 0.0054 | 0 | 0 | <0.005 | - |
| Sc | 0.0265 | 0.0197 | 0.0228 | 0.0224 | 0.0174 | 0.0188 | 0.0176 | 0.021 | 15.99 |
| Ti | 0.1232 | 0.1258 | 0.1435 | 0.1309 | 0.1304 | 0.0997 | 0.121 | 0.12 | 10.67 |
| V | 0.1619 | 0.1585 | 0.153 | 0.1461 | 0.1662 | 0.1486 | 0.1502 | 0.15 | 4.8 |
| Cr | 0.0327 | 0.0299 | 0.023 | 0.0543 | 0.0486 | 0.0402 | 0.0359 | 0.038 | 28.69 |
| Mn | 0.0315 | 0.0412 | 0.0369 | 0.0346 | 0.0337 | 0.0368 | 0.0348 | 0.036 | 8.61 |
| Fe | 0.7158 | 0.7292 | 0.6809 | 0.6871 | 0.6477 | 0.6601 | 0.697 | 0.69 | 4.2 |
| Co | 0.0063 | 0.0055 | 0.0089 | 0.0073 | 0.0051 | 0.0016 | 0.0056 | 0.0058 | 39.07 |
| Ni | 0.2124 | 0.227 | 0.2425 | 0.1823 | 0.2023 | 0.1659 | 0.204 | 0.21 | 12.58 |
| Cu | 0.4349 | 0.4022 | 0.3943 | 0.4024 | 0.3758 | 0.4047 | 0.3569 | 0.4 | 6.19 |
| Zn | 0.6347 | 0.5005 | 0.504 | 0.4808 | 0.439 | 0.7572 | 0.6474 | 0.57 | 20.32 |
| Ga | 0.045 | 0.0342 | 0.0441 | 0.0542 | 0.032 | 0.0227 | 0.027 | 0.037 | 30.14 |
| Ge | 0 | 0.0329 | 0 | 0.0676 | 0 | 0 | 0 | 0.014 | 184.48 |
| As | 0.0028 | 0 | 0 | 0.0139 | 0.0084 | 0 | 0 | <0.005 | - |
| Se | 0.2218 | 0.2173 | 0.2367 | 0.204 | 0.1306 | 0.2751 | 0.2206 | 0.22 | 20.27 |
| Br | 0.0043 | 0.0057 | 0.0032 | 0.0018 | 0.0043 | 0 | 0.003 | <0.005 | - |
| Rb | 0.0038 | 0.0022 | 0 | 0.0023 | 0.0045 | 0 | 0 | <0.005 | - |
| Sr | 0.0003 | 0 | 0 | 0 | 0 | 0 | 0 | <0.005 | - |
| Y | 0 | 0 | 0.0012 | 0.0023 | 0.0003 | 0.0046 | 0 | <0.005 | - |
| Zr | 0.0104 | 0.0159 | 0.041 | 0.0207 | 0.0416 | 0.0295 | 0.0143 | 0.025 | 51.6 |
| Nb | 0.0022 | 0.0007 | 0.0011 | 0.0014 | 0.0014 | 0 | 0 | <0.005 | - |
| Mo | 0.0127 | 0.0306 | 0.0186 | 0.0188 | 0.0261 | 0.0173 | 0.0257 | 0.021 | 29.08 |
| Ru | 0 | 0 | 0 | 0 | 0.0005 | 0.0003 | 0.0016 | <0.005 | - |
| Rh | 0 | 0.0043 | 0 | 0.0022 | 0 | 0 | 0.0052 | <0.005 | - |
| Pd | 0.0726 | 0.0527 | 0.0498 | 0.0252 | 0.0543 | 0.0359 | 0.0812 | 0.053 | 36.52 |
| Ag | 0.0119 | 0.0356 | 0.0189 | 0.0217 | 0.0262 | 0.012 | 0.0186 | 0.021 | 40.13 |
| Cd | 0.013 | 0.0252 | 0.051 | 0.0645 | 0.0649 | 0.0521 | 0.0273 | 0.043 | 48.43 |
| In | 0.0008 | 0.0064 | 0.0057 | 0 | 0.0041 | 0 | 0 | <0.005 | - |
| Sn | 0.0195 | 0.0143 | 0.016 | 0.0174 | 0.0437 | 0.016 | 0.0122 | 0.02 | 54.12 |
| Sb | 0.0172 | 0.0429 | 0.0308 | 0.0498 | 0.0314 | 0.0553 | 0.0176 | 0.035 | 42.76 |
| Te | 0 | 0 | 0 | 0 | 0 | 0.0002 | 0 | <0.005 | - |
| I | 0.0022 | 0 | 0 | 0.0033 | 0.0006 | 0.0008 | 0.0015 | <0.005 | - |
| Cs | 0 | 0 | 0 | 0.0033 | 0.0066 | 0.0047 | 0 | <0.005 | - |
| Ba | 0.0021 | 0 | 0 | 0.0025 | 0.0013 | 0 | 0 | <0.005 | - |
| La | 0.0014 | 0 | 0.0007 | 0.0007 | 0.0035 | 0.0005 | 0 | <0.005 | - |
| Ce | 0.0019 | 0.0004 | 0.0005 | 0.0023 | 0.0014 | 0 | 0 | <0.005 | - |
| Pr | 0.0004 | 0 | 0 | 0 | 0 | 0 | 0 | <0.005 | - |
| Nd | 0 | 0 | 0 | 0.0028 | 0 | 0.0198 | 0 | <0.005 | - |
| Sm | 0 | 0 | 0.0066 | 0.0067 | 0 | 0 | 0 | <0.005 | - |
| Eu | 0 | 0 | 0.0029 | 0 | 0.0052 | 0.0042 | 0.0042 | <0.005 | - |
| Gd | 0 | 0 | 0 | 0 | 0.0071 | 0 | 0 | <0.005 | - |
| Tb | 0 | 0.0025 | 0 | 0.0006 | 0.009 | 0.0017 | 0 | <0.005 | - |
| Dy | 0 | 0 | 0 | 0.0066 | 0.0017 | 0 | 0 | <0.005 | - |
| Ho | 0 | 0 | 0 | 0.0009 | 0.0049 | 0 | 0 | <0.005 | - |
| Er | 0 | 0 | 0 | 0 | 0.0043 | 0 | 0 | <0.005 | - |
| Tm | 0 | 0 | 0 | 0.0012 | 0.0029 | 0 | 0 | <0.005 | - |
| Yb | 0.0034 | 0 | 0.0082 | 0 | 0.0016 | 0 | 0 | <0.005 | - |
| Lu | 0 | 0.0036 | 0 | 0 | 0.0023 | 0 | 0 | <0.005 | - |
| Hf | 0.0238 | 0.0138 | 0.0218 | 0.0236 | 0.0269 | 0.0112 | 0.02 | 0.02 | 28.21 |
| Ta | 0.0211 | 0.0191 | 0.0187 | 0.0202 | 0.021 | 0.0163 | 0.02 | 0.019 | 8.53 |
| W | 0.0115 | 0.0212 | 0.0509 | 0.0599 | 0.0201 | 0.057 | 0.0551 | 0.039 | 52.76 |
| Re | 0.0306 | 0.0296 | 0.0183 | 0.032 | 0.0313 | 0.0225 | 0.0451 | 0.03 | 28.21 |
| Os | 0 | 0.0083 | 0 | 0.0125 | 0.0126 | 0 | 0 | <0.005 | - |
| Ir | 0 | 0.0039 | 0.008 | 0 | 0.0182 | 0 | 0 | <0.005 | - |
| Pt | 0.0315 | 0.0379 | 0 | 0.0232 | 0.0707 | 0 | 0 | 0.023 | 112.81 |
| Au | 0 | 0.0038 | 0 | 0.0116 | 0 | 0 | 0 | <0.005 | - |
| Hg | 0 | 0.005 | 0 | 0.0014 | 0.0003 | 0 | 0 | <0.005 | - |
| Tl | 0.0143 | 0.0246 | 0.0124 | 0.0189 | 0.019 | 0.0125 | 0.0122 | 0.016 | 28.98 |
| Pb | 0.0128 | 0.0069 | 0.002 | 0.0056 | 0.0213 | 0.002 | 0.002 | 0.0075 | 96.16 |
| Bi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | <0.005 | - |
| Th | 0.002 | 0.0015 | 0 | 0 | 0 | 0 | 0.0007 | <0.005 | - |
| U | 0.0039 | 0.0005 | 0 | 0.0049 | 0.0055 | 0.0023 | 0 | <0.005 | - |

表9 金川集团5N铝样品测定数据

| 元素 | 分析结果（n=7） | | | | | | | 平均值  *w*/(µg /g) | RSD  % |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0.004 | 0.005 | 0.005 | 0.005 | 0.003 | 0.006 | 0.001 | 0.004 | 40.28 |
| Be | 0.000 | 0.175 | 0.007 | 0.008 | 0.100 | 0.000 | 0.008 | 0.042 | 161.00 |
| B | 0.103 | 0.129 | 0.093 | 0.060 | 0.135 | 0.343 | 0.099 | 0.138 | 68.38 |
| F | 0.226 | 0.261 | 0.246 | 0.222 | 0.224 | 0.247 | 0.271 | 0.243 | 7.90 |
| Na | 0.222 | 0.188 | 0.167 | 0.136 | 0.133 | 0.125 | 0.157 | 0.161 | 21.42 |
| Mg | 0.057 | 0.083 | 0.080 | 0.111 | 0.101 | 0.134 | 0.094 | 0.094 | 26.14 |
| Si | 1.725 | 1.604 | 1.714 | 1.718 | 1.666 | 1.696 | 1.507 | 1.661 | 4.81 |
| P | 0.935 | 0.893 | 0.649 | 0.773 | 0.806 | 0.661 | 0.615 | 0.762 | 16.39 |
| S | 3.276 | 2.988 | 2.972 | 2.858 | 2.479 | 2.477 | 2.473 | 2.789 | 11.41 |
| Cl | 0.254 | 0.242 | 0.210 | 0.243 | 0.195 | 0.244 | 0.159 | 0.221 | 15.58 |
| K | 0.280 | 0.237 | 0.198 | 0.204 | 0.228 | 0.205 | 0.192 | 0.221 | 14.00 |
| Ca | 0.006 | 0.081 | 0.154 | 0.134 | 0.103 | 0.013 | 0.013 | 0.072 | 85.63 |
| Sc | 0.027 | 0.037 | 0.046 | 0.034 | 0.028 | 0.032 | 0.018 | 0.032 | 27.05 |
| Ti | 0.200 | 0.195 | 0.217 | 0.230 | 0.224 | 0.226 | 0.222 | 0.216 | 6.26 |
| V | 0.260 | 0.242 | 0.225 | 0.284 | 0.269 | 0.245 | 0.250 | 0.254 | 7.65 |
| Cr | 0.065 | 0.069 | 0.088 | 0.116 | 0.072 | 0.044 | 0.066 | 0.074 | 30.47 |
| Mn | 0.052 | 0.073 | 0.073 | 0.095 | 0.072 | 0.080 | 0.058 | 0.072 | 19.53 |
| Fe | 1.001 | 0.996 | 1.011 | 0.951 | 0.937 | 0.957 | 0.874 | 0.961 | 4.95 |
| Co | 0.000 | 0.022 | 0.011 | 0.006 | 0.005 | 0.033 | 0.006 | 0.012 | 98.38 |
| Ni | 0.278 | 0.313 | 0.334 | 0.362 | 0.234 | 0.242 | 0.293 | 0.294 | 15.87 |
| Cu | 0.711 | 0.763 | 0.679 | 0.875 | 0.789 | 0.627 | 0.733 | 0.740 | 10.82 |
| Zn | 2.310 | 2.124 | 2.156 | 2.210 | 1.737 | 2.104 | 1.971 | 2.088 | 8.90 |
| Ga | 0.044 | 0.062 | 0.023 | 0.081 | 0.236 | 0.123 | 0.054 | 0.089 | 81.16 |
| Ge | 0.203 | 0.241 | 0.041 | 0.000 | 0.014 | 0.197 | 0.014 | 0.102 | 105.01 |
| As | 0.386 | 0.184 | 0.268 | 0.266 | 0.340 | 0.293 | 0.223 | 0.280 | 24.34 |
| Se | 0.017 | 0.255 | 0.018 | 0.212 | 0.018 | 0.250 | 0.035 | 0.115 | 101.77 |
| Br | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Rb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Y | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Zr | 0.009 | 0.008 | 0.014 | 0.013 | 0.072 | 0.008 | 0.007 | 0.019 | 126.86 |
| Nb | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 4.74 |
| Mo | 0.01 | 0.012 | 0.01 | 0.012 | 0.01 | 0.012 | 0.011 | 0.011 | 8.94 |
| Ru | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Rh | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ag | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Cd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| In | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sn | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Te | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| I | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Cs | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ba | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| La | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ce | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Nd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sm | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Eu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Gd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Dy | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ho | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Er | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tm | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Yb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Lu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Hf | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ta | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| W | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Re | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Os | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ir | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pt | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Au | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Hg | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tl | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pb | 0.194 | 0.147 | 0.099 | 0.145 | 0.179 | 0.098 | 0.125 | 0.141 | 26.14 |
| Bi | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Th | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| U | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |

表10 新疆众合4N铝样品测定数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0.078 | 0.065 | 0.033 | 0.056 | 0.104 | 0.067 | 0.081 | 0.069 | 39 |
| Be | 0.007 | 0.014 | 0.035 | 0.020 | 0.014 | 0.035 | 0.021 | 0.021 | 31 |
| B | 0.964 | 1.253 | 1.302 | 1.046 | 1.174 | 1.461 | 1.128 | 1.190 | 9.7 |
| F |  |  |  |  |  |  |  |  | #DIV/0! |
| Na | 0.069 | 0.094 | 0.082 | 0.058 | 0.074 | 0.062 | 0.052 | 0.070 | 22 |
| Mg | 0.817 | 0.780 | 0.891 | 0.840 | 0.958 | 0.943 | 0.902 | 0.876 | 7.3 |
| Si | 5.573 | 6.352 | 6.313 | 5.725 | 6.329 | 5.472 | 5.780 | 5.935 | 6.9 |
| P | 0.145 | 0.103 | 0.072 | 0.106 | 0.087 | 0.104 | 0.110 | 0.104 | 26 |
| S | 0.562 | 0.445 | 0.484 | 0.479 | 0.375 | 0.445 | 0.509 | 0.471 | 15 |
| Cl | 0.117 | 0.170 | 0.125 | 0.155 | 0.152 | 0.123 | 0.133 | 0.139 | 18 |
| K | 0.015 | 0.004 | 0.003 | 0.006 | 0.004 | 0.008 | 0.017 | 0.008 | 63 |
| Ca | 0.080 | 0.030 | 0.015 | 0.052 | 0.064 | 0.033 | 0.055 | 0.047 | 79 |
| Sc | 0.013 | 0.011 | 0.016 | 0.004 | 0.017 | 0.010 | 0.019 | 0.013 | 54 |
| Ti | 0.696 | 0.718 | 0.762 | 0.730 | 0.719 | 0.827 | 0.801 | 0.751 | 2.9 |
| V | 0.989 | 0.935 | 1.027 | 0.936 | 1.127 | 1.035 | 1.137 | 1.026 | 7.7 |
| Cr | 0.730 | 0.773 | 0.870 | 0.783 | 0.842 | 0.959 | 1.036 | 0.856 | 5.9 |
| Mn | 3.548 | 3.702 | 3.720 | 3.933 | 3.502 | 4.346 | 4.279 | 3.862 | 3.9 |
| Fe | 1.818 | 1.931 | 1.812 | 1.774 | 1.650 | 1.815 | 1.990 | 1.827 | 5.6 |
| Co | 0.000 | 0.001 | 0.002 | 0.000 | 0.000 | 0.002 | 0.000 | 0.001 | 50 |
| Ni | 0.021 | 0.034 | 0.044 | 0.000 | 0.077 | 0.034 | 0.000 | 0.030 | 84 |
| Cu | 0.016 | 0.033 | 0.035 | 0.012 | 0.020 | 0.021 | 0.021 | 0.023 | 48 |
| Zn | 4.305 | 4.002 | 4.027 | 4.631 | 5.415 | 4.314 | 4.239 | 4.419 | 14 |
| Ga | 5.010 | 4.930 | 4.741 | 4.304 | 4.811 | 4.795 | 4.827 | 4.774 | 5.7 |
| Ge | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 | 0.015 | 0.000 | 0.003 | 23 |
| As | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Se | 0.017 | 0.008 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Br | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Rb | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Sr | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | <0.005 | - |
| Y | 0.050 | 0.031 | 0.050 | 0.060 | 0.038 | 0.052 | 0.065 | 0.049 | 22 |
| Zr | 0.470 | 0.408 | 0.438 | 0.457 | 0.547 | 0.547 | 0.463 | 0.476 | 9.5 |
| Nb | 0.014 | 0.009 | 0.009 | 0.007 | 0.008 | 0.017 | 0.009 | 0.010 | 16 |
| Mo | 0.676 | 0.718 | 0.727 | 0.639 | 0.740 | 0.740 | 0.701 | 0.706 | 5.6 |
| Ru | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Rh | 0.000 | 0.031 | 0.022 | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 | - |
| Pd | 0.000 | 0.075 | 0.089 | 0.000 | 0.000 | 0.000 | 0.000 | 0.023 | - |
| Ag | 0.000 | 0.005 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | - |
| Cd | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.012 | 0.002 | - |
| In | 0.010 | 0.000 | 0.001 | 0.000 | 0.002 | 0.002 | 0.012 | 0.004 | 181 |
| Sn | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Sb | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Te | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| I | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Cs | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | <0.005 | - |
| Ba | 0.002 | 0.008 | 0.006 | 0.004 | 0.003 | 0.004 | 0.003 | 0.004 | 53 |
| La | 0.366 | 0.339 | 0.351 | 0.385 | 0.409 | 0.377 | 0.365 | 0.370 | 7.3 |
| Ce | 0.497 | 0.507 | 0.517 | 0.465 | 0.485 | 0.539 | 0.435 | 0.492 | 3.8 |
| Pr | 0.010 | 0.018 | 0.010 | 0.021 | 0.020 | 0.017 | 0.024 | 0.017 | 31 |
| Nd | 0.098 | 0.088 | 0.083 | 0.111 | 0.094 | 0.078 | 0.043 | 0.085 | 14 |
| Sm | 0.006 | 0.002 | 0.000 | 0.012 | 0.038 | 0.045 | 0.020 | 0.018 | 34 |
| Eu | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Gd | 0.028 | 0.014 | 0.035 | 0.030 | 0.030 | 0.020 | 0.024 | 0.026 | 41 |
| Tb | 0.007 | 0.008 | 0.009 | 0.007 | 0.003 | 0.004 | 0.004 | 0.006 | 55 |
| Dy | 0.017 | 0.046 | 0.049 | 0.013 | 0.042 | 0.033 | 0.038 | 0.034 | 51 |
| Ho | 0.007 | 0.000 | 0.008 | 0.008 | 0.010 | 0.015 | 0.008 | 0.008 | 27 |
| Er | 0.018 | 0.011 | 0.000 | 0.023 | 0.019 | 0.014 | 0.028 | 0.016 | 67 |
| Tm | 0.002 | 0.000 | 0.000 | 0.002 | 0.002 | 0.002 | 0.000 | 0.001 | 54 |
| Yb | 0.000 | 0.000 | 0.000 | 0.007 | 0.000 | 0.005 | 0.005 | 0.002 | 61 |
| Lu | 0.001 | 0.000 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 95 |
| Hf | 0.000 | 0.003 | 0.003 | 0.000 | 0.038 | 0.000 | 0.000 | <0.005 | - |
| Ta | 0.074 | 0.067 | 0.055 | 0.051 | 0.075 | 0.065 | 0.069 | 0.065 | 17 |
| W | 0.278 | 0.220 | 0.163 | 0.252 | 0.203 | 0.164 | 0.129 | 0.201 | 27 |
| Re | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | <0.005 | - |
| Os | 0.021 | 0.000 | 0.000 | 0.008 | 0.009 | 0.006 | 0.000 | 0.006 | 147 |
| Ir | 0.006 | 0.000 | 0.000 | 0.007 | 0.004 | 0.018 | 0.009 | 0.006 | 18 |
| Pt | 0.031 | 0.000 | 0.000 | 0.027 | 0.014 | 0.005 | 0.020 | 0.014 | 297 |
| Au | 0.000 | 0.000 | 0.008 | 0.009 | 0.006 | 0.000 | 0.000 | <0.005 | - |
| Hg | 0.006 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | <0.005 | - |
| Tl | 0.000 | 0.003 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | <0.005 | - |
| Pb | 0.009 | 0.009 | 0.006 | 0.009 | 0.013 | 0.014 | 0.019 | 0.011 | 16 |
| Bi | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.002 | <0.005 | - |
| Th | 0.010 | 0.023 | 0.018 | 0.012 | 0.011 | 0.011 | 0.008 | 0.014 | 50 |
| U | 0.151 | 0.159 | 0.203 | 0.169 | 0.151 | 0.156 | 0.156 | 0.164 | 14 |

表11 昆明冶金研究院4N铝样品测定数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0.009 | 0.007 | 0.001 | 0.002 | 0.003 | 0.010 | 0.004 | 0.005 | 67 |
| Be | 0.009 | 0.006 | 0.003 | 0.005 | 0.004 | 0.005 | 0.006 | 0.005 | 37 |
| B | 0.005 | 0.004 | 0.004 | 0.005 | 0.004 | 0.004 | 0.005 | <0.005 | - |
| F | 0.319 | 0.235 | 0.196 | 0.253 | 0.234 | 0.195 | 0.191 | 0.230 | 20 |
| Na | 0.125 | 0.136 | 0.113 | 0.153 | 0.115 | 0.136 | 0.149 | 0.130 | 12 |
| Mg | 0.140 | 0.140 | 0.137 | 0.162 | 0.129 | 0.137 | 0.130 | 0.140 | 7.9 |
| Si | 2.514 | 2.360 | 2.382 | 3.622 | 2.355 | 2.475 | 2.496 | 2.600 | 18 |
| P | 0.552 | 0.364 | 0.324 | 0.165 | 0.423 | 0.345 | 0.341 | 0.360 | 32 |
| S | 0.005 | 0.010 | 0.009 | 0.009 | 0.006 | 0.001 | 0.001 | 0.006 | 65 |
| Cl | 0.002 | 0.002 | 0.002 | 0.005 | 0.004 | 0.003 | 0.002 | <0.005 | - |
| K | 0.100 | 0.094 | 0.096 | 0.087 | 0.093 | 0.086 | 0.102 | 0.090 | 6.5 |
| Ca | 0.014 | 0.051 | 0.058 | 0.026 | 0.025 | 0.064 | 0.028 | 0.038 | 51 |
| Sc | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 8.5 |
| Ti | 0.189 | 0.108 | 0.149 | 0.122 | 0.105 | 0.181 | 0.177 | 0.150 | 24 |
| V | 0.110 | 0.125 | 0.133 | 0.101 | 0.123 | 0.118 | 0.125 | 0.120 | 8.9 |
| Cr | 1.113 | 1.126 | 1.126 | 1.132 | 1.121 | 1.124 | 1.129 | 1.120 | 0.5 |
| Mn | 3.643 | 3.665 | 3.665 | 3.608 | 3.695 | 3.695 | 3.687 | 3.670 | 0.9 |
| Fe | 3.348 | 3.373 | 3.380 | 3.317 | 3.333 | 3.369 | 3.361 | 3.350 | 0.7 |
| Co | 2.574 | 2.568 | 1.988 | 1.887 | 2.523 | 2.126 | 2.115 | 2.250 | 13 |
| Ni | 0.006 | 0.001 | 0.004 | 0.006 | 0.002 | 0.003 | 0.004 | 0.004 | 50 |
| Cu | 0.011 | 0.046 | 0.058 | 0.063 | 0.011 | 0.022 | 0.034 | 0.035 | 61 |
| Zn | 1.497 | 1.656 | 1.606 | 1.584 | 1.730 | 1.643 | 1.607 | 1.620 | 4.4 |
| Ga | 2.982 | 2.982 | 2.937 | 2.983 | 2.032 | 2.965 | 2.128 | 2.720 | 16 |
| Ge | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.003 | <0.005 | - |
| As | 0.084 | 0.098 | 0.152 | 0.189 | 0.151 | 0.123 | 0.174 | 0.120 | 28 |
| Se | 0.092 | 0.094 | 0.096 | 0.096 | 0.100 | 0.093 | 0.092 | 0.100 | 2.9 |
| Br | 0.382 | 0.433 | 0.475 | 0.414 | 0.386 | 0.313 | 0.268 | 0.380 | 18 |
| Rb | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Sr | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Y | 0.005 | 0.005 | 0.006 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 16 |
| Zr | 0.169 | 0.180 | 0.097 | 0.163 | 0.169 | 0.105 | 0.091 | 0.140 | 28 |
| Nb | 0.001 | 0.001 | 0.002 | 0.003 | 0.003 | 0.001 | 0.002 | <0.005 | - |
| Mo | 0.172 | 0.173 | 0.175 | 0.166 | 0.143 | 0.192 | 0.188 | 0.170 | 9.4 |
| Ru | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Rh | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 | 0.000 | 0.001 | <0.005 | - |
| Pd | 0.009 | 0.011 | 0.008 | 0.010 | 0.015 | 0.005 | 0.004 | 0.009 | 44 |
| Ag | 0.005 | 0.000 | 0.000 | 0.010 | 0.007 | 0.002 | 0.005 | 0.004 | 87 |
| Cd | 0.008 | 0.009 | 0.010 | 0.012 | 0.005 | 0.009 | 0.007 | 0.009 | 24 |
| In | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Sn | 0.011 | 0.006 | 0.007 | 0.009 | 0.009 | 0.009 | 0.008 | 0.008 | 21 |
| Sb | 0.008 | 0.010 | 0.003 | 0.008 | 0.010 | 0.003 | 0.007 | 0.007 | 41 |
| Te | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| I | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 | 0.001 | <0.005 | - |
| Cs | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | <0.005 | - |
| Ba | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| La | 0.034 | 0.043 | 0.043 | 0.033 | 0.033 | 0.036 | 0.041 | 0.038 | 12 |
| Ce | 0.039 | 0.049 | 0.052 | 0.035 | 0.036 | 0.049 | 0.046 | 0.044 | 16 |
| Pr | 0.001 | 0.001 | 0.001 | 0.001 | 0.010 | 0.001 | 0.002 | <0.005 | - |
| Nd | 0.008 | 0.007 | 0.005 | 0.007 | 0.009 | 0.009 | 0.002 | 0.007 | 40 |
| Sm | 0.003 | 0.002 | 0.002 | 0.003 | 0.005 | 0.011 | 0.012 | 0.005 | 82 |
| Eu | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Gd | 0.005 | 0.003 | 0.004 | 0.005 | 0.001 | 0.008 | 0.008 | <0.005 | - |
| Tb | 0.001 | 0.000 | 0.000 | 0.002 | 0.001 | 0.001 | 0.000 | <0.005 | - |
| Dy | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.002 | 0.004 | <0.005 | - |
| Ho | 0.001 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | <0.005 | - |
| Er | 0.003 | 0.002 | 0.001 | 0.002 | 0.006 | 0.002 | 0.006 | 0.003 | 66 |
| Tm | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 | <0.005 | - |
| Yb | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 | 0.000 | 0.000 | <0.005 | - |
| Lu | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Hf | 0.000 | 0.001 | 0.002 | 0.003 | 0.000 | 0.001 | 0.002 | <0.005 | - |
| Ta | 0.099 | 0.090 | 0.072 | 0.098 | 0.100 | 0.076 | 0.085 | 0.089 | 13 |
| W | 0.009 | 0.003 | 0.004 | 0.007 | 0.002 | 0.005 | 0.012 | 0.006 | 67 |
| Re | 0.085 | 0.095 | 0.099 | 0.100 | 0.088 | 0.085 | 0.087 | 0.091 | 7.1 |
| Os | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Ir | 0.002 | 0.005 | 0.007 | 0.005 | 0.008 | 0.006 | 0.007 | 0.006 | 35 |
| Pt | 0.013 | 0.010 | 0.013 | 0.010 | 0.009 | 0.007 | 0.009 | 0.010 | 22 |
| Au | 0.008 | 0.009 | 0.008 | 0.008 | 0.007 | 0.007 | 0.006 | 0.008 | 11 |
| Hg | 0.004 | 0.006 | 0.004 | 0.012 | 0.010 | 0.006 | 0.006 | 0.007 | 47 |
| Tl | 0.032 | 0.059 | 0.053 | 0.035 | 0.052 | 0.050 | 0.005 | 0.041 | 46 |
| Pb | 0.006 | 0.002 | 0.002 | 0.004 | 0.001 | 0.001 | 0.002 | <0.005 | - |
| Bi | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Th | 0.001 | 0.000 | 0.001 | 0.007 | 0.001 | 0.001 | 0.001 | <0.005 | - |
| U | 0.018 | 0.021 | 0.018 | 0.019 | 0.016 | 0.024 | 0.030 | 0.021 | 23 |

表12 深圳万泽中南4N铝样品测定数据

| **元素** | **分析结果（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | 0.041 | 0.030 | 0.025 | 0.036 | 0.029 | 0.045 | 0.027 | 0.033 | 23 |
| Be | 0.026 | 0.032 | 0.047 | 0.029 | 0.035 | 0.029 | 0.039 | 0.034 | 22 |
| B | 3.575 | 3.568 | 3.892 | 3.545 | 3.425 | 3.261 | 3.610 | 3.550 | 5.4 |
| F | 0.227 | 0.156 | 0.151 | 0.129 | 0.118 | 0.092 | 0.100 | 0.140 | 33 |
| Na | 0.031 | 0.036 | 0.035 | 0.037 | 0.032 | 0.029 | 0.022 | 0.032 | 16 |
| Mg | 0.724 | 0.845 | 0.725 | 0.870 | 0.829 | 0.823 | 0.808 | 0.800 | 7.1 |
| Si | 10.789 | 9.811 | 10.583 | 9.505 | 9.921 | 9.441 | 10.276 | 10.050 | 5.2 |
| P | 0.171 | 0.190 | 0.192 | 0.213 | 0.181 | 0.165 | 0.199 | 0.190 | 8.9 |
| S | 0.422 | 0.359 | 0.364 | 0.345 | 0.167 | 0.275 | 0.217 | 0.310 | 29 |
| Cl | 0.407 | 0.303 | 0.252 | 0.250 | 0.189 | 0.162 | 0.130 | 0.240 | 38 |
| K | 0.021 | 0.021 | 0.013 | 0.006 | 0.007 | 0.013 | 0.005 | 0.012 | 55 |
| Ca | 0.034 | 0.042 | 0.009 | 0.067 | 0.017 | 0.025 | 0.025 | 0.031 | 61 |
| Sc | 0.009 | 0.006 | 0.010 | 0.007 | 0.011 | 0.008 | 0.009 | 0.009 | 20 |
| Ti | 0.614 | 0.597 | 0.569 | 0.563 | 0.558 | 0.563 | 0.535 | 0.570 | 4.6 |
| V | 0.694 | 0.675 | 0.693 | 0.678 | 0.674 | 0.683 | 0.616 | 0.670 | 4.0 |
| Cr | 0.656 | 0.575 | 0.626 | 0.490 | 0.679 | 0.596 | 0.548 | 0.600 | 11 |
| Mn | 3.128 | 3.127 | 3.098 | 3.263 | 3.152 | 3.124 | 3.087 | 3.140 | 1.9 |
| Fe | 2.271 | 2.164 | 2.235 | 2.298 | 2.238 | 2.162 | 2.100 | 2.210 | 3.2 |
| Co | 0.018 | 0.009 | 0.011 | 0.013 | 0.012 | 0.010 | 0.014 | 0.012 | 23 |
| Ni | 0.086 | 0.086 | 0.052 | 0.070 | 0.069 | 0.060 | 0.065 | 0.070 | 18 |
| Cu | 0.037 | 0.028 | 0.022 | 0.030 | 0.029 | 0.026 | 0.027 | 0.028 | 16 |
| Zn | 1.188 | 1.158 | 1.269 | 1.251 | 1.111 | 1.134 | 1.175 | 1.180 | 4.9 |
| Ga | 4.190 | 4.230 | 4.260 | 4.393 | 4.323 | 4.053 | 4.347 | 4.260 | 2.7 |
| Ge | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| As | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.000 | <0.005 | - |
| Se | 0.092 | 0.134 | 0.052 | 0.040 | 0.081 | 0.092 | 0.117 | 0.087 | 38 |
| Br | 0.006 | 0.006 | 0.005 | 0.003 | 0.002 | 0.007 | 0.001 | <0.005 | - |
| Rb | 0.001 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.002 | <0.005 | - |
| Sr | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Y | 0.019 | 0.015 | 0.016 | 0.023 | 0.018 | 0.015 | 0.018 | 0.018 | 16 |
| Zr | 0.383 | 0.417 | 0.371 | 0.372 | 0.412 | 0.370 | 0.364 | 0.380 | 5.6 |
| Nb | 0.002 | 0.002 | 0.001 | 0.001 | 0.003 | 0.001 | 0.002 | <0.005 | - |
| Mo | 0.369 | 0.366 | 0.392 | 0.301 | 0.333 | 0.345 | 0.292 | 0.340 | 11 |
| Ru | 0.003 | 0.004 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | <0.005 | - |
| Rh | 0.002 | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 | 0.000 | <0.005 | - |
| Pd | 0.049 | 0.041 | 0.031 | 0.039 | 0.049 | 0.051 | 0.043 | 0.043 | 16 |
| Ag | 0.025 | 0.016 | 0.013 | 0.025 | 0.019 | 0.022 | 0.022 | 0.020 | 23 |
| Cd | 0.000 | 0.009 | 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | <0.005 | - |
| In | 0.000 | 0.001 | 0.000 | 0.001 | 0.002 | 0.002 | 0.000 | <0.005 | - |
| Sn | 0.000 | 0.006 | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 | <0.005 | - |
| Sb | 0.009 | 0.013 | 0.009 | 0.008 | 0.010 | 0.014 | 0.009 | 0.010 | 22 |
| Te | 0.016 | 0.016 | 0.013 | 0.028 | 0.030 | 0.017 | 0.016 | 0.019 | 34 |
| I | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.002 | 0.001 | <0.005 | - |
| Cs | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Ba | 0.004 | 0.001 | 0.001 | 0.002 | 0.002 | 0.000 | 0.002 | <0.005 | - |
| La | 0.256 | 0.233 | 0.238 | 0.249 | 0.255 | 0.252 | 0.221 | 0.240 | 5.4 |
| Ce | 0.268 | 0.273 | 0.244 | 0.252 | 0.242 | 0.237 | 0.217 | 0.250 | 7.7 |
| Pr | 0.008 | 0.007 | 0.005 | 0.008 | 0.009 | 0.008 | 0.007 | 0.007 | 18 |
| Nd | 0.044 | 0.040 | 0.042 | 0.036 | 0.046 | 0.039 | 0.038 | 0.041 | 8.6 |
| Sm | 0.005 | 0.000 | 0.008 | 0.005 | 0.006 | 0.000 | 0.006 | <0.005 | - |
| Eu | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | <0.005 | - |
| Gd | 0.015 | 0.005 | 0.010 | 0.020 | 0.005 | 0.012 | 0.008 | 0.011 | 51 |
| Tb | 0.001 | 0.000 | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 | <0.005 | - |
| Dy | 0.008 | 0.006 | 0.007 | 0.010 | 0.005 | 0.005 | 0.006 | 0.007 | 26 |
| Ho | 0.004 | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | <0.005 | - |
| Er | 0.002 | 0.010 | 0.007 | 0.003 | 0.002 | 0.005 | 0.009 | 0.006 | 59 |
| Tm | 0.001 | 0.002 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | <0.005 | - |
| Yb | 0.000 | 0.000 | 0.000 | 0.004 | 0.004 | 0.005 | 0.000 | <0.005 | - |
| Lu | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | <0.005 | - |
| Hf | 0.007 | 0.005 | 0.006 | 0.009 | 0.007 | 0.010 | 0.009 | 0.007 | 26 |
| Ta | 0.018 | 0.020 | 0.024 | 0.022 | 0.020 | 0.020 | 0.014 | 0.020 | 15 |
| W | 0.084 | 0.053 | 0.109 | 0.073 | 0.059 | 0.059 | 0.075 | 0.073 | 26 |
| Re | 0.012 | 0.007 | 0.013 | 0.010 | 0.021 | 0.022 | 0.013 | 0.014 | 39 |
| Os | 0.000 | 0.000 | 0.011 | 0.000 | 0.004 | 0.000 | 0.000 | <0.005 | - |
| Ir | 0.000 | 0.000 | 0.006 | 0.000 | 0.000 | 0.003 | 0.000 | <0.005 | - |
| Pt | 0.017 | 0.011 | 0.016 | 0.015 | 0.013 | 0.009 | 0.014 | 0.013 | 21 |
| Au | 0.011 | 0.004 | 0.006 | 0.000 | 0.011 | 0.000 | 0.003 | <0.005 | - |
| Hg | 0.040 | 0.030 | 0.037 | 0.053 | 0.057 | 0.048 | 0.029 | 0.042 | 27 |
| Tl | 0.019 | 0.021 | 0.020 | 0.041 | 0.014 | 0.014 | 0.036 | 0.023 | 46 |
| Pb | 0.006 | 0.005 | 0.006 | 0.003 | 0.006 | 0.004 | 0.003 | <0.005 | - |
| Bi | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | <0.005 | - |
| Th | 0.004 | 0.004 | 0.008 | 0.004 | 0.006 | 0.002 | 0.005 | <0.005 | - |
| U | 0.098 | 0.082 | 0.101 | 0.091 | 0.077 | 0.097 | 0.083 | 0.090 | 10 |

表13 金川集团4N铝样品测定数据

| 元素 | 分析结果（n=7） | | | | | | | 平均值  *w*/(µg /g) | RSD  % |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Li | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Be | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| B | 2.095 | 2.223 | 2.646 | 2.709 | 2.822 | 2.472 | 2.736 | 2.529 | 10.95 |
| F | 0.325 | 0.296 | 0.298 | 0.293 | 0.257 | 0.272 | 0.252 | 0.285 | 9.12 |
| Na | 0.365 | 0.273 | 0.296 | 0.240 | 0.268 | 0.234 | 0.242 | 0.274 | 16.61 |
| Mg | 0.766 | 0.732 | 0.684 | 0.819 | 0.826 | 0.785 | 0.736 | 0.764 | 6.65 |
| Si | 12.698 | 12.671 | 12.773 | 12.631 | 13.094 | 12.992 | 12.667 | 12.789 | 1.42 |
| P | 0.158 | 0.230 | 0.194 | 0.156 | 0.196 | 0.198 | 0.172 | 0.186 | 13.98 |
| S | 2.923 | 2.675 | 2.638 | 2.703 | 2.565 | 2.286 | 2.354 | 2.592 | 8.36 |
| Cl | 0.342 | 0.302 | 0.254 | 0.263 | 0.231 | 0.211 | 0.210 | 0.259 | 18.88 |
| K | 0.434 | 0.354 | 0.362 | 0.333 | 0.257 | 0.274 | 0.242 | 0.323 | 21.24 |
| Ca | 0.017 | 0.012 | 0.029 | 0.006 | 0.000 | 0.006 | 0.025 | 0.014 | 79.02 |
| Sc | 0.008 | 0.016 | 0.006 | 0.006 | 0.016 | 0.006 | 0.008 | 0.009 | 49.45 |
| Ti | 0.623 | 0.591 | 0.648 | 0.639 | 0.594 | 0.619 | 0.607 | 0.617 | 3.50 |
| V | 0.930 | 0.930 | 0.906 | 0.914 | 0.906 | 0.935 | 0.859 | 0.911 | 2.86 |
| Cr | 0.822 | 0.894 | 0.850 | 0.878 | 0.901 | 0.847 | 0.784 | 0.854 | 4.88 |
| Mn | 4.511 | 4.424 | 4.501 | 4.507 | 4.513 | 4.486 | 4.431 | 4.482 | 0.85 |
| Fe | 2.760 | 2.754 | 2.619 | 2.637 | 2.672 | 2.619 | 2.630 | 2.670 | 2.32 |
| Co | 0.005 | 0.010 | 0.008 | 0.021 | 0.010 | 0.012 | 0.006 | 0.010 | 51.51 |
| Ni | 0.064 | 0.059 | 0.075 | 0.070 | 0.075 | 0.069 | 0.073 | 0.069 | 8.85 |
| Cu | 0.233 | 0.249 | 0.201 | 0.198 | 0.203 | 0.195 | 0.211 | 0.213 | 9.63 |
| Zn | 9.641 | 10.627 | 11.468 | 11.186 | 10.329 | 10.128 | 9.727 | 10.444 | 6.66 |
| Ga | 6.023 | 6.074 | 6.458 | 6.199 | 6.460 | 6.636 | 6.158 | 6.287 | 3.68 |
| Ge | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| As | 0.047 | 0.016 | 0.048 | 0.033 | 0.017 | 0.000 | 0.033 | 0.028 | 63.12 |
| Se | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Br | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Rb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Y | 0.034 | 0.038 | 0.030 | 0.025 | 0.028 | 0.022 | 0.022 | 0.028 | 22.35 |
| Zr | 0.393 | 0.447 | 0.348 | 0.454 | 0.373 | 0.441 | 0.451 | 0.416 | 10.39 |
| Nb | 0.010 | 0.007 | 0.015 | 0.014 | 0.014 | 0.010 | 0.015 | 0.012 | 26.06 |
| Mo | 0.550 | 0.582 | 0.552 | 0.651 | 0.531 | 0.522 | 0.614 | 0.572 | 8.16 |
| Ru | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Rh | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ag | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Cd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| In | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sn | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Te | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| I | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Cs | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ba | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| La | 0.274 | 0.280 | 0.280 | 0.281 | 0.240 | 0.283 | 0.251 | 0.270 | 6.40 |
| Ce | 0.342 | 0.318 | 0.345 | 0.255 | 0.304 | 0.326 | 0.279 | 0.310 | 10.69 |
| Pr | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Nd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Sm | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Eu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Gd | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Dy | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ho | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Er | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tm | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Yb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Lu | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Hf | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ta | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| W | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Re | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Os | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Ir | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pt | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Au | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Hg | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Tl | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Pb | 0.405 | 0.384 | 0.402 | 0.333 | 0.270 | 0.264 | 0.303 | 0.337 | 18.01 |
| Bi | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |
| Th | 0.019 | 0.010 | 0.006 | 0.009 | 0.017 | 0.013 | 0.012 | 0.012 | 36.82 |
| U | 0.157 | 0.150 | 0.138 | 0.151 | 0.159 | 0.182 | 0.165 | 0.157 | 8.82 |

利用辉光放电质谱法对纯铝中杂质元素进行分析测定，本方法测定全元素共73种元素，共两个水平样品，由于数据量较大，因此选取有代表性的不同水平的元素为代表这一含量范围的元素进行数理统计，结果如表14~28所示：

表14 4N纯铝样品Si统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Si测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 6.745 | 6.430 | 6.506 | 6.544 | 6.780 | 6.521 | 6.569 | 6.585 | 1.9 |
| 2 | 5.573 | 6.352 | 6.313 | 5.725 | 6.329 | 5.472 | 5.780 | 5.935 | 0.065 |
| 3 | 2.514 | 2.360 | 2.382 | 3.622 | 2.355 | 2.475 | 2.496 | 2.600 | 17 |
| 4 | 6.789 | 6.811 | 6.583 | 6.505 | 6.921 | 6.441 | 6.276 | 6.62 | 3.5 |
| 5 | 12.698 | 12.671 | 12.773 | 12.631 | 13.094 | 12.992 | 12.667 | 12.789 | 1.42 |

表15 4N纯铝样品Mn统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Mn测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 4.572 | 4.620 | 4.573 | 4.611 | 4.593 | 4.638 | 4.750 | 4.622 | 1.3 |
| 2 | 3.548 | 3.702 | 3.720 | 3.933 | 3.502 | 4.346 | 4.279 | 3.862 | 0.088 |
| 3 | 3.643 | 3.665 | 3.665 | 3.608 | 3.695 | 3.695 | 3.687 | 3.670 | 0.86 |
| 4 | 3.128 | 3.127 | 3.098 | 3.263 | 3.152 | 3.124 | 3.087 | 3.140 | 1.9 |
| 5 | 4.511 | 4.424 | 4.501 | 4.507 | 4.513 | 4.486 | 4.431 | 4.482 | 0.85 |

表16 4N纯铝样品Fe统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Fe测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 4.126 | 4.110 | 4.090 | 4.116 | 4.108 | 4.132 | 4.151 | 4.12 0 | 0.47 |
| 2 | 1.818 | 1.931 | 1.812 | 1.774 | 1.650 | 1.815 | 1.990 | 1.827 | 0.060 |
| 3 | 3.348 | 3.373 | 3.380 | 3.317 | 3.333 | 3.369 | 3.361 | 3.350 | 0.69 |
| 4 | 2.271 | 2.164 | 2.235 | 2.298 | 2.238 | 2.162 | 2.100 | 2.210 | 3.2 |
| 5 | 2.760 | 2.754 | 2.619 | 2.637 | 2.672 | 2.619 | 2.630 | 2.670 | 2.32 |

表17 4N纯铝样品Zn统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Zn测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 2.013 | 2.038 | 2.035 | 2.054 | 2.018 | 2.002 | 2.120 | 2.040 | 1.9 |
| 2 | 4.305 | 4.002 | 4.027 | 4.631 | 5.415 | 4.314 | 4.239 | 4.419 | 0.11 |
| 3 | 1.497 | 1.656 | 1.606 | 1.584 | 1.730 | 1.643 | 1.607 | 1.620 | 4.4 |
| 4 | 1.188 | 1.158 | 1.269 | 1.251 | 1.111 | 1.134 | 1.175 | 1.180 | 4.9 |
| 5 | 9.641 | 10.627 | 11.468 | 11.186 | 10.329 | 10.128 | 9.727 | 10.444 | 6.66 |

表18 4N纯铝样品Ga统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Ga测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 7.020 | 7.021 | 7.020 | 7.020 | 7.020 | 7.021 | 7.022 | 7.021 | 0.010 |
| 2 | 5.010 | 4.930 | 4.741 | 4.304 | 4.811 | 4.795 | 4.827 | 4.774 | 0.047 |
| 3 | 2.982 | 2.982 | 2.937 | 2.983 | 2.032 | 2.965 | 2.128 | 2.720 | 16 |
| 4 | 4.190 | 4.230 | 4.260 | 4.393 | 4.323 | 4.053 | 4.347 | 4.260 | 2.7 |
| 5 | 6.023 | 6.074 | 6.458 | 6.199 | 6.460 | 6.636 | 6.158 | 6.287 | 3.68 |

表19 4N纯铝样品Mo统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Mo测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.501 | 0.507 | 0.504 | 0.503 | 0.505 | 0.504 | 0.501 | 0.503 | 0.41 |
| 2 | 0.676 | 0.718 | 0.727 | 0.639 | 0.740 | 0.740 | 0.701 | 0.706 | 0.05 |
| 3 | 0.172 | 0.173 | 0.175 | 0.166 | 0.143 | 0.192 | 0.188 | 0.170 | 9.3 |
| 4 | 0.369 | 0.366 | 0.392 | 0.301 | 0.333 | 0.345 | 0.292 | 0.340 | 11 |
| 5 | 0.550 | 0.582 | 0.552 | 0.651 | 0.531 | 0.522 | 0.614 | 0.572 | 8.16 |

表20 4N纯铝样品Ti统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Ti测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.404 | 0.423 | 0.428 | 0.476 | 0.422 | 0.442 | 0.456 | 0.440 | 5.56 |
| 2 | 0.696 | 0.718 | 0.762 | 0.730 | 0.719 | 0.827 | 0.801 | 0.751 | 0.06 |
| 3 | 0.189 | 0.108 | 0.149 | 0.122 | 0.105 | 0.181 | 0.177 | 0.150 | 24.39 |
| 4 | 0.614 | 0.597 | 0.569 | 0.563 | 0.558 | 0.563 | 0.535 | 0.570 | 4.58 |
| 5 | 0.623 | 0.591 | 0.648 | 0.639 | 0.594 | 0.619 | 0.607 | 0.617 | 3.50 |

表21 5N纯铝样品Mg统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Mg测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.111 | 0.110 | 0.106 | 0.111 | 0.108 | 0.112 | 0.110 | 0.110 | 1.8 |
| 2 | 0.081 | 0.0645 | 0.0738 | 0.0833 | 0.078 | 0.108 | 0.0714 | 0.080 | 0.17 |
| 3 | 0.0117 | 0.0384 | 0.0265 | 0.0242 | 0.0148 | 0.0494 | 0.0114 | 0.025 | 57 |
| 4 | 0.0806 | 0.0892 | 0.0945 | 0.0633 | 0.0877 | 0.0652 | 0.0659 | 0.078 | 17 |
| 5 | 0.057 | 0.083 | 0.080 | 0.111 | 0.101 | 0.134 | 0.094 | 0.094 | 26.14 |

表22 5N纯铝样品Fe统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Fe测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.626 | 0.631 | 0.629 | 0.631 | 0.640 | 0.619 | 0.637 | 0.631 | 1.1 |
| 2 | 0.535 | 0.432 | 0.4289 | 0.5273 | 0.6406 | 0.483 | 0.4695 | 0.502 | 0.15 |
| 3 | 0.1982 | 0.1112 | 0.1105 | 0.1131 | 0.1163 | 0.1 | 0.1146 | 0.120 | 27 |
| 4 | 0.7158 | 0.7292 | 0.6809 | 0.6871 | 0.6477 | 0.6601 | 0.697 | 0.690 | 4.2 |
| 5 | 1.001 | 0.996 | 1.011 | 0.951 | 0.937 | 0.957 | 0.874 | 0.961 | 4.95 |

表23 5N纯铝样品Ni统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Ni测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.243 | 0.269 | 0.236 | 0.210 | 0.230 | 0.234 | 0.237 | 0.237 | 7.41 |
| 2 | 0.2429 | 0.1523 | 0.2624 | 0.216 | 0.2375 | 0.1455 | 0.13 | 0.198 | 0.27 |
| 3 | 0.1293 | 0.0928 | 0.0968 | 0.1556 | 0.0944 | 0.0932 | 0.0919 | 0.110 | 23.18 |
| 4 | 0.2124 | 0.227 | 0.2425 | 0.1823 | 0.2023 | 0.1659 | 0.204 | 0.210 | 12.58 |
| 5 | 0.278 | 0.313 | 0.334 | 0.362 | 0.234 | 0.242 | 0.293 | 0.294 | 15.87 |

表24 5N纯铝样品Zn统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Zn测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.421 | 0.383 | 0.372 | 0.363 | 0.367 | 0.377 | 0.424 | 0.387 | 6.6 |
| 2 | 1.0105 | 0.896 | 0.8435 | 1.0932 | 0.8929 | 0.9271 | 0.8225 | 0.926 | 0.10 |
| 3 | 0.3259 | 0.3645 | 0.3801 | 0.301 | 0.5129 | 0.294 | 0.4232 | 0.370 | 21 |
| 4 | 0.6347 | 0.5005 | 0.504 | 0.4808 | 0.439 | 0.7572 | 0.6474 | 0.570 | 20 |
| 5 | 2.310 | 2.124 | 2.156 | 2.210 | 1.737 | 2.104 | 1.971 | 2.088 | 8.90 |

表25 5N纯铝样品Pb统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Pb测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.006 | 0.006 | 0.006 | 0.007 | 0.007 | 0.006 | 0.007 | 0.007 | 8.89 |
| 2 | 0.0092 | 0.021 | 0.0112 | 0.0142 | 0.0342 | 0.0168 | 0.0106 | 0.0167 | 0.52 |
| 3 | 0.0043 | 0.0027 | 0.006 | 0.0033 | 0.0012 | 0.0024 | 0.0026 | 0.0167 | - |
| 4 | 0.0128 | 0.0069 | 0.002 | 0.0056 | 0.0213 | 0.002 | 0.002 | 0.0075 | 96.16 |
| 5 | 0.194 | 0.147 | 0.099 | 0.145 | 0.179 | 0.098 | 0.125 | 0.141 | 26.14 |

表26 5N纯铝样品Nb统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Nb测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 4.7 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0017 | 0.0002 | 2.6 |
| 3 | 0.0033 | 0.0032 | 0.0052 | 0.0075 | 0.0056 | 0.0056 | 0.0062 | 0.005 | 29 |
| 4 | 0.0033 | 0.0032 | 0.0052 | 0.0075 | 0.0056 | 0.0056 | 0.0062 | 0.005 | 29 |
| 5 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 4.74 |

表27 5N纯铝样品La统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **La测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.006 | 0.007 | 0.006 | 0.008 | 0.006 | 0.007 | 0.006 | 0.007 | 11 |
| 2 | 0.0008 | 0.0017 | 0.0028 | 0.0008 | 0.0022 | 0.0014 | 0.0009 | 0.0015 | 0.51 |
| 3 | 0 | 0.0003 | 0.0003 | 0.0043 | 0.0012 | 0.0003 | 0 | <0.005 | - |
| 4 | 0.0014 | 0 | 0.0007 | 0.0007 | 0.0035 | 0.0005 | 0 | <0.005 | - |
| 5 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - |

表28 5N纯铝样品Be统计数据

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **实验室** | **Be测试数据（n=7）** | | | | | | | **平均值**  ***w*/(mg/kg)** | **RSD**  **%** |
| 1 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 | <0.005 | - |
| 2 | 0.0114 | 0 | 0 | 0 | 0 | 0.0063 | 0 | 0.0025 | 1.8 |
| 3 | 0.0025 | 0.0035 | 0.0066 | 0.0027 | 0.0063 | 0.0072 | 0.0061 | 0.005 | 40 |
| 4 | 0.0026 | 0.0221 | 0.0187 | 0.0081 | 0.011 | 0.0248 | 0 | 0.013 | 67 |
| 5 | 0.000 | 0.175 | 0.007 | 0.008 | 0.100 | 0.000 | 0.008 | 0.042\* | 161.00 |

统计不同含量范围的代表性元素，剔除离群值，统计相对偏差，结果如表29所示：

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **元素** | **平均值**  ***w*/(mg/kg)** | | | | | **相对偏差**  **%** | **扩大后允许**  **相对偏差%** |
| Si | 6.585 | 5.935 | 2.600 | 6.620 | 12.789\* | 73.9 | 100 |
| Mn | 4.622 | 3.862 | 3.670 | 3.140 | 4.482 | 38.8 | 100 |
| Fe | 4.120 | 1.827 | 3.350 | 2.210 | 2.670 | 79.7 | 100 |
| Zn | 2.040 | 4.419\* | 1.620 | 1.180 | 2.088 | 53.3 | 100 |
| Ga | 7.021 | 4.774 | 2.720 | 4.260 | 6.287 | 91.6 | 100 |
| Mo | 0.503 | 0.706 | 0.170 | 0.340 | 0.572 | 124 | 150 |
| Ti | 0.44 | 0.751 | 0.150 | 0.570 | 0.617 | 126 | 150 |
| Mg | 0.110 | 0.080 | 0.025 | 0.078 | 0.094 | 116 | 150 |
| Fe | 0.631 | 0.502 | 0.120 | 0.690 | 0.961 | 117 | 150 |
| Ni | 0.237 | 0.198 | 0.110 | 0.210 | 0.294 | 67 | 150 |
| Zn | 0.387 | 0.927 | 0.370 | 0.570 | 2.088 | 99 | 150 |
| Pb | 0.007 | 0.017 | 0.017 | 0.008 | 0.141 | 86 | 200 |
| Nb | 0.005 | 0.000 | 0.005 | 0.005 | 0.005 | 127 | 200 |
| La | 0.007\* | 0.002 | 0.001 | 0.001 | <0.005 | 52 | 200 |
| Be | <0.005 | 0.0025 | 0.005 | 0.013 | 0.042\* | 154 | 200 |
| 注：带\*作为离群值剔除。 | | | | | | | |

辉光放电质谱法目前在国内的应用大部分检测基本上是进行半定量分析，即控制仪器操作的计算机中软件中的“典型相对灵敏度因子”自动计算出各元素的质量分数；有的厂家也购置价格比较昂贵的纯铝标样进行定量分析，即通过在与被测试样相同的分析条件、离子源结构以及测试条件下对标准样品进行独立测定获得标准曲线和相对灵敏度因子，应用该相对灵敏度因子计算出各元素的质量分数。

根据以上辉光放电质谱法的特点和实际检测应用，结合上述数据统计结果，规定此标准的精密度用扩大后的相对偏差进行表示，如表30进行表示：

表30 允许相对偏差

|  |  |
| --- | --- |
| **元素含量范围*w*/(mg/kg)** | **允许相对偏差%** |
| ≥0.005～0.10 | 200 |
| ≥0.10～0.50 | 150 |
| ≥0.5～5.0 | 100 |
| ≥5.0～10.0 | 50 |

**四 标准水平分析**

**4.1 国际、国外同类标准水平的对比分析**

通过文献检索，网上查询，国外标准有ASTM F1593-2008测定27种杂质元素，国内只有本标准修订的YS/T 871-2013测定40种元素，而本次修订后元素种类由原来的40种增加至测定73种杂质元素，即全元素。这在国际是独一无二的，因此确定该标准总体水平为国际先进水平。

**4.2 与现有标准及制定中标准协调配套的情况**

本标准是作为纯铝分析方法标准，与GB/T 1196-2017《重熔用铝锭》、GB/T 8733-2016《铸造铝合金锭》、GB/T 3190-2008《变形铝及铝合金化学成分》、GB/T 27677－2017《铝中间合金》 YS/T 282－2008《铝中间合金锭》、GB T 33912-2017 《高纯金属为原料的变形铝及铝合金铸锭》等产品标准相配套，同时又与YS/T 870-2020《纯铝化学分析方法 痕量杂质元素的测定电感耦合等离子体质谱法》互相配合，互为补充衔接配套。

**五、与现行相关法律、法规、规章及相关标准的协调性**

纯铝是高技术高附加值材料，随着现代科技的进步及新材料研究领域的不断发展，对纯铝的纯度和需求量也将会随之增加，期间势必涉及纯铝产品纯度等问题。因此，研究和建立一种针对纯铝中杂质元素含量的快速、准确的分析方法对相关产业的发展有着十分重要的意义。本标准符合现有国家产业政策，符合相关法律规章，在纯铝行业的发展领域发挥一定的作用。

**六、是否涉及专利及知识产权的说明**

本文件修订过程中没有检索到专利和知识产权问题。

**七、重大分歧意见的处理过程**

本标准属于有色金属领域专业基础标准，编制组根据修订前确定的编制原则进行标准修订，在标准修订稿征求意见过程中未发生重大分歧意见。

**八、作为强制性、推荐性国家标准的建议**

制定纯铝辉光放电质谱标准非常适应市场的需求，因此，建议本标准作为推荐性行业标准发布实施。

**九、贯彻标准的要求和措施建议**

制定后的标准颁布实施后，需要国家有关部门组织大力宣传和贯彻，主办各种形式的培训班，才能让稀土企业及相关贸易单位充分认识和理解新标准条款，进而加以应用。

**十、废止现行有关标准的建议**

无废止标准的建议。

**十一、其他应予以说明的事项**

无其他应予以说明的事项。

**十二、推广应用的预期效果**

近些年来，我国有色金属的发展日新月异，产量和质量都得到了极大的提高。特别是纯铝是高技术高附加值材料，它主要应用在一些高技术领域和科学研究用。例如精铝(3N8~4N8)的78%左右用于轧制电解电容器铝箔，即常说的电子箔，照明灯具的用量占12%，其他用途的为6%，计算机存储硬盘的用量约4%。超纯铝(5N~6N，每种杂质的最大含量0.4ppb的95%用于制造半导体器件，5%用作超导电缆的稳定化材料。纯铝中的杂质含量严重影响它的性能，所以纯铝的分析检测方法也变得尤为重要。因此建立一种更加科学、准确、快速、更加适用的分析检测方法标准来对纯铝行业进行技术支撑，以满足各种产品化学成分分析检测。

本次修订对原标准做了部分修改、补充，无论是在待测元素的种类还是在方法的适用性、可操作性上都有了很大的提高和扩充，达到国际先进水平要求。新版标准全面反映了我国铝及铝合金化学检测技术水平，有利于促进国内铝生产企业进一步完善分析检测手段，满足中国铝工业的实际使用和未来发展的需求，为中国铝工业的发展提供了基础性的技术支撑。

《纯铝化学分析方法 痕量杂质元素的测定 辉光放电质谱法》

编制组

2022年7月