

QOTHO CERTIFIED REFERENCE MATERIAL (QCRM)

QCRM-1-240

FERROCHROME

CERTIFICATE OF ANALYSIS

| CERTIFIED VALUES | | | |
|--|-------|----------------|----------------------|
| ANALYTES | UNITS | CONCENTRATIONS | EXPANDED UNCERTAINTY |
| Al | % | 0.61 | ±0.04 |
| C | % | 5.94 | ±0.06 |
| Co | % | 0.063 | ±0.002 |
| Cr | % | 44.23 | ±0.13 |
| Fe | % | 38.85 | ±0.38 |
| Mn | % | 0.262 | ±0.004 |
| Ni | % | 0.23 | ±0.01 |
| P | % | 0.017 | ±0.002 |
| S | % | 0.075 | ±0.004 |
| Si | % | 5.20 | ±0.07 |
| Ti | % | 0.50 | ±0.01 |
| V | % | 0.33 | ±0.01 |
| ASSIGNED VALUES (FOR INFORMATION ONLY) | | | |
| ANALYTES | UNITS | CONCENTRATIONS | EXPANDED UNCERTAINTY |
| Mg | % | 0.45 | ±0.04 |

1. Use:

QCRM-1-240 is a certified reference material which is suitable for use as random control samples in routine analytical laboratory quality control, when inserted within a batch of samples and measured in parallel to the unknown. The QCRM can also be used as a control sample in the analysis of samples of a similar type, verification of analytical methods for Chrome Ferrochrome and as a calibration standard for the calibration of equipment used for analysing similar materials.

2. Origin of Material:

This standard was sponsored by Glencore Wonderkop Smelter.

3. Mineral and Chemical Composition:

Ferrochrome is a metallic product of pyrometallurgical processing of the chromite ore or foundry sand, both of which are naturally occurring materials. From the molten alloy state, the alloy is cast and crushed into a lump size product of <2mm in size. The alloy has main phases of (Cr,Fe)7C3, (Cr,Fe)23C6, traces (Fe,Cr)3C carbides, Cr containing α -Fe, Cr-Si and traces of S, P, along with minor (<0,5%) amounts of Mn, V, Ti - all species are present in alloy form.

4. Date of Initial Issue:

04 June 2024.

5. Packaging & Handling instructions:

The material was packaged as 100g unit sizes, placed in geo-envelopes, within a vacuum sealed aluminium foil bag. Open the seal of the foil with care and shake or otherwise agitate prior to use. Normal safety precautions for handling fine particulate matter are recommended, such as the use of safety glasses, breathing protection, gloves, and a laboratory coat. Once opened, material must be stored in a cool, dry environment. Results on page 1 is presented on dry basis. Analysis should therefore be done on dry basis, after drying to constant mass, at 105 degrees Celsius.

6. Method of Preparation:

The material was sieved through a 75-micron screen and the oversize was re-milled to ensure 100% passing through the screen. It was then blended, systematically divided, and packaged into 100-gram zip-lock bags. Randomly selected samples, from the bags, were tested in-house via XRF, to confirm homogeneity. Once confirmed and certification completed, the items were placed in geo-envelopes and vacuum sealed in aluminium foil bags.

7. Methods of Analysis used:

- Sodium peroxide fusion with ICP-OES finish
- Aqua Regia digestion with ICP-OES finish
- Fused beads with XRF finish
- Pressed pellet with XRF finish
- Chrome by sodium peroxide fusion with Potentiometric Titration
- Chrome by aqua regia digestion with Potentiometric Titration
- Silica by sodium peroxide fusion and gravimetric finish
- Sulphur by combustion analysis.

8. Analysis required:

An instruction letter was sent to all participants. The analysis required was noted in the instruction letter and reporting template, including but not limited to Al, C, Co, Cr, Fe, Mg, Mn, Ni, P, S, Si, Ti and V.

9. Participating Laboratories:

| NO | LABORATORY | COUNTRY |
|-----|------------------------------------|----------------|
| 1. | Afarak Elektrowerk Weisweiler GmbH | Germany |
| 2. | AHK North West | South Africa |
| 3. | AHK Richards Bay | South Africa |
| 4. | ALS Inspection UK | United Kingdom |
| 5. | Columbus Analytical Lab | South Africa |
| 6. | Cotecna Richards Bay | South Africa |
| 7. | Glencore Boshhoek | South Africa |
| 8. | Glencore Lion | South Africa |
| 9. | Glencore Rustenburg Smelter | South Africa |
| 10. | Glencore Wonderkop Smelter | South Africa |
| 11. | Intertek Steelpoort | South Africa |
| 12. | Mintek | South Africa |
| 13. | Mitra Sk India | India |
| 14. | Outokumpu | Finland |
| 15. | PCL Rustenburg | South Africa |
| 16. | PCL Steelpoort | South Africa |
| 17. | Samancor Dikwena | South Africa |
| 18. | Samancor Ferrrometals | South Africa |
| 19. | Samancor TCS Laboratory | South Africa |
| 20. | Samancor Tubatse Alloy Smelter | South Africa |
| 21. | Samancor Tubatse Chrome | South Africa |
| 22. | SGS Netherlands BV | Netherlands |
| 23. | UIS Analytical Services | South Africa |
| 24. | Zimasco Kwekwe | Zimbabwe |



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10. Assay Data:
 Data used for Assigning Values and Certification.

| LABORATORY | Al | C | Co | Cr | Fe | Mg | Mn | Ni | P | S | Si | Ti | V |
|------------|-------|-------|-------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| UNIT | % | % | % | % | % | % | % | % | % | % | % | % | % |
| LAB001 | | | | | | 0.44 | | | | | | | |
| LAB002 | 0.606 | | | 44.335 | 38.89 | 0.446 | 0.256 | 0.2 | 0.115 | | 5.095 | 0.481 | 0.351 |
| LAB003 | 0.575 | | | 44.33 | | 0.56 | 0.26 | 0.22 | 0.019 | | | | 0.33 |
| LAB004 | | 5.866 | 0.063 | 44.147 | 38.627 | 0.463 | 0.259 | 0.228 | 0.021 | 0.055 | 5.186 | 0.499 | 0.332 |
| LAB005 | | | | 44.042 | | | | | | | | | |
| LAB006 | | 5.937 | 0.064 | 44.125 | 38.477 | 0.261 | 0.261 | 0.241 | 0.015 | 0.074 | 5.186 | 0.505 | 0.325 |
| LAB007 | | | | 44.148 | | | | | | | | | |
| LAB008 | | | | 44.43 | 38.735 | 0.485 | 0.27 | | | | 5.165 | 0.5 | |
| LAB009 | 0.619 | 6 | 0.063 | 44.05 | 39.1 | | 0.265 | 0.22 | 0.017 | 0.076 | 5.15 | 0.515 | 0.325 |
| LAB010 | 0.596 | 5.83 | 0.064 | 44.57 | 39.71 | 0.514 | 0.266 | 0.231 | 0.02 | 0.066 | 5.546 | | 0.334 |
| LAB011 | | | | 44.445 | | | | | | | | | |
| LAB012 | | 5.95 | | 44.485 | 39.11 | | | | 0.016 | 0.081 | 5.23 | | |
| LAB013 | | 5.915 | 0.062 | 43.926 | 39.175 | | 0.263 | 0.225 | 0.02 | 0.073 | 5.224 | 0.505 | 0.336 |
| LAB014 | | | | 44.076 | | | | | | | | | |
| LAB015 | | 5.941 | 0.061 | 44.02 | 39.047 | 0.477 | 0.258 | 0.231 | 0.018 | 0.074 | 5.282 | 0.507 | 0.334 |
| LAB016 | | | | 43.982 | | | | | | | | | |
| LAB017 | | 5.867 | 0.063 | 44.555 | 38.665 | 0.462 | 0.26 | 0.228 | 0.018 | 0.072 | 5.11 | 0.504 | 0.331 |
| LAB018 | | | | 44.43 | | | | | | | | | |
| LAB019 | 0.62 | 5.84 | | | 39.5 | | 0.267 | | | 0.078 | 5.28 | | |
| LAB020 | | | | 44.1 | | | | | | | | | |
| LAB021 | 0.774 | 6.006 | 0.063 | | 38.354 | 0.41 | 0.256 | 0.225 | 0.015 | 0.077 | 5.22 | 0.496 | 0.331 |
| LAB022 | | | | 44.547 | | | | | | | | | |
| LAB023 | 0.56 | 5.975 | 0.063 | 44.435 | 38.75 | | 0.26 | 0.23 | 0.015 | 0.074 | 5.15 | 0.5 | 0.325 |
| LAB024 | | | | 44.4 | | | | | | | | | |



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| LABORATORY | Al | C | Co | Cr | Fe | Mg | Mn | Ni | P | S | Si | Ti | V |
|------------|-------|-------|-------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| UNIT | % | % | % | % | % | % | % | % | % | % | % | % | % |
| LAB025 | 0.635 | | 0.064 | | 38.055 | | 0.262 | 0.149 | 0.018 | | 5.37 | 0.509 | 0.328 |
| LAB026 | | | | 43.72 | | | | | | | | | |
| LAB027 | | | | 31.51 | | | | | | | | | |
| LAB028 | 0.596 | 6.178 | | 43.82 | 38.53 | 0.438 | 0.257 | 0.231 | 0.014 | 0.097 | 5.469 | | |
| LAB029 | | 5.94 | 0.03 | 44.236 | 43.864 | 0.394 | 0.239 | 0.216 | 0.012 | 0.067 | 5.206 | 0.537 | 0.333 |
| LAB030 | | | | 46.273 | | | | | | | | | |
| LAB031 | | | 0.061 | | | 0.429 | 0.291 | 0.204 | 0.014 | | 5.22 | 0.464 | 0.31 |
| LAB032 | | 5.99 | 0.063 | 44.215 | | 0.463 | 0.269 | 0.227 | 0.024 | 0.079 | 5.044 | 0.473 | 0.32 |
| LAB033 | 0.609 | | 0.067 | | 39.61 | | 0.27 | 0.235 | 0.019 | 0.08 | 5.295 | 0.51 | |
| LAB034 | | | | 44.37 | | | | | | | | | |
| LAB035 | 0.662 | 5.995 | 0.063 | | 39.21 | | 0.26 | 0.23 | 0.015 | 0.073 | 5.09 | 0.51 | 0.33 |
| LAB036 | | | | 44.195 | | | | | | | | | |
| LAB037 | | | 0.065 | | 38.765 | 0.33 | 0.269 | 0.228 | 0.017 | 0.083 | 5.135 | 0.498 | 0.287 |
| LAB038 | | | | 44.22 | | | | | | | | | |
| LAB039 | | | | | 37.6 | 0.49 | 0.24 | 0.21 | | 0.07 | 4.995 | | 0.315 |

11. Method of Certification:

QM is a SANAS Accredited Proficiency Testing Scheme Provider, No. PTS0012

This material was distributed as test items, in the Qotho Chrome PT Round 2 of 2023. The participating laboratories were each given 1 randomly selected sample from the batch, to analyse and report on in duplicate. Some laboratories reported results via more than one analytical method. Obvious blunders were resolved with the laboratories (if any), after which the data was processed using Robust Statistics, through PROLab Plus.

Not all the participating laboratories were accredited. Historical performance in Qotho PT Schemes, as well as an evaluation of the CRM QA/QC data generated by the laboratories, during the analysis of this QRM, were considered, to evaluate the competence of laboratories. Where competence could not be confirmed, the affected data was deselected from the dataset. Certification of analytes was then done, provided that a minimum of 10 qualifying datapoints remained available.

Where analytes could not be certified, estimate concentrations were assigned, using all the data in the dataset.

12. Measurement of Uncertainty:

Standard uncertainty, u_{CRM} , was calculated according to ISO 13528:2022 (equation 6), and it includes the effects of uncertainty due to inhomogeneity, transport, potential instability, and laboratory uncertainty. Because of all the uncertainties under consideration, QM further applies an expanded uncertainty, for certification purposes. The measurement uncertainty of the certified value is therefore calculated as follows: $U_{CRM} = k u_{CRM}$, where k is a coverage factor, which is determined from the Student's t -distribution, based on the degrees of freedom, per analyte. This presents a certified value, as follows: $x_{CRM} \pm U_{CRM}$.

Measurement uncertainty for Assigned values, are calculated in the same manner.

Laboratories which prefer to use the 95% measurement uncertainty, rather than the expanded uncertainty, all available information relating to measurement uncertainty of the certified/assigned values, are given below:

| Analyte | Unit of measure | s (Standard Deviation of Dataset) | ν (Degrees of Freedom) | k (Coverage Factor) | u (Standard Uncertainty) | 95% Measurement Uncertainty | Expanded Uncertainty |
|---------|-----------------|--|-------------------------------|--------------------------|-------------------------------|-----------------------------|----------------------|
| Al | % | 0.041 | 10 | 2.228 | 0.015 | ± 0.03 | ± 0.04 |
| C | % | 0.075 | 14 | 2.145 | 0.025 | ± 0.05 | ± 0.06 |
| Co | % | 0.001 | 15 | 2.131 | 0.001 | ± 0.002 | ± 0.002 |
| Cr | % | 0.287 | 29 | 2.045 | 0.061 | ± 0.12 | ± 0.13 |
| Fe | % | 0.632 | 19 | 2.093 | 0.18 | ± 0.36 | ± 0.38 |
| Mg | % | 0.055 | 15 | 2.131 | 0.018 | ± 0.04 | ± 0.04 |
| Mn | % | 0.007 | 20 | 2.086 | 0.002 | ± 0.004 | ± 0.004 |
| Ni | % | 0.010 | 19 | 2.093 | 0.003 | ± 0.01 | ± 0.01 |
| P | % | 0.004 | 19 | 2.093 | 0.001 | ± 0.002 | ± 0.002 |
| S | % | 0.007 | 17 | 2.110 | 0.002 | ± 0.004 | ± 0.004 |
| Si | % | 0.127 | 21 | 2.080 | 0.032 | ± 0.06 | ± 0.07 |
| Ti | % | 0.012 | 16 | 2.120 | 0.003 | ± 0.01 | ± 0.01 |
| V | % | 0.010 | 17 | 2.110 | 0.002 | ± 0.01 | ± 0.01 |

13. Metrological Traceability:

The values quoted herein are based on the consensus values derived from statistical analysis of the data from an inter laboratory measurement program. Traceability to SI units is via the accredited laboratories, as ISO/IEC 17025:2017 requires laboratories to use CRM's traceable to the SI units, during the calibration of their equipment. Not all laboratories were accredited.

Fortunately, most laboratories reported on the QA/QC CRMs used during the analysis of this QRM and reported the values obtained during the sample run. Evaluation of their QA/QC performance serves as further evidence of metrological traceability.

Equivalence tests were performed on all analytes to determine whether the metrologically traceable data and those for which traceability evidence was not available, could be treated as equal (at a level of significance of $\alpha = 0.05$). Where equivalent, all the data was used. Where not equivalent, only the metrologically traceable data was considered.

14. Minimum sample size:

The recommended minimum sample size for the use of this material is as per the participants method validation criteria.

15. Period of validity:

The certified values are valid for this product, while still sealed in its original packaging, for a minimum period of 5 years from date of Initial Certification. Stability monitoring of inventory will be done at regular intervals. Any concerns regarding potential instability of the material, will immediately be communicated to all consumers.

16. Legal:

This certificate and the reference material described in it were prepared with due care and attention. The requirements of ISO Guide 31, ISO/IEC 17043:2023 and ISO 17034:2016 were followed in the preparation of this reference material and certificate of analysis.

Qotho Minerals, however, accepts no liability for any decisions or actions taken following the use of the reference material. The company has a complaints procedure, which will be made available upon request, should there be any dissatisfaction with either the product or the CoA.

| | |
|--|---|
| Certifying & Technical Signatories | |
| | |
| <i>Dr Hannelie de Beer (Pr. Sci. Nat.)</i> | <i>Takudzwa Tsapayi (Pr. Sci. Nat.)</i> |
| 04 June 2024 | |

This Certificate of Analysis (CoA) has been electronically signed using an Advanced Electronic Signature (AES) in terms of the Electronic Communications and Transactions Act No. 15, 2002 (ECT Act). Any amendments to the CoA can be detected by reference to the Signature Panel displayed in the electronic pdf version of the CoA.

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