

FACTORES INTERELEMENTALES PARA ANALISIS GEOQUIMICO POR  
FLUORESCENCIA DE RAYOS X

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## RESUMEN

Los factores interelementales alfa o de efecto de absorci6n de masa son calculados para 35 elementos de inter6s geoqu6mico, afectados por 65 elementos interferentes de igual inter6s geoqu6mico y abundancia. Se consideran el concepto de longitud de onda efectiva del elemento analizado y un factor geom6trico del espectr6metro de 1.5. La variaci6n sistem6tica del factor alfa con el n6mero at6mico define sus aplicaciones y correcciones pertinentes en geoqu6mica anal6tica.

## ABSTRACT

The interelement correction factors alfa or mass absorption correction factors are computed for 35 elements of geochemical interest affected by 65 interfering elements of equal geochemical interest and abundance. The concept of effective wavelength of the analyzed element and a spectrometer geometrical factor of 1.5 are used. The systematic variation of the alfa factors with the atomic number defines applications and pertinent corrections in analytical geochemistry.

En el an6lisis geoqu6mico por espectrometrfa de rayos x, la concentraci6n del elemento analizado es calculada de la intensidad de la radiaci6n caracterfstica seg6n diferentes modelos y algoritmos (de Pablo-Gal6n, 1976, 1977, 1978,) que incluyen en una u otra forma el efecto interelemental o efecto de los varios componentes de la roca sobre el elemento analizado.

El efecto interelemental o factor alfa se define por la ecuaci6n 1 (Jenkins, 1974), que considera los coeficientes de absorci6n de masa de los elementos analizado e interferente a las longitudes de onda caracterfstica y efectiva del elemento analizado. Es un factor relativo en cuanto a que emplea la longitud

$$\alpha_{AB} = \frac{\mu_B(\lambda) + A \mu_B(\lambda_A)}{\mu_A(\lambda) + A \mu_A(\lambda_A)} - 1 \quad (1)$$

|                   |  |
|-------------------|--|
| $\alpha_{AB}$     | factor alfa o efecto del elemento analizado A sobre el interferente B  |
| $\mu_B(\lambda)$  | coeficiente de absorci6n de masa del elemento interferente B a la longitud de onda efectiva $\lambda$ del elemento A |
| $\mu_A(\lambda)$  | coeficiente de absorci6n de masa del elemento analizado A a su longitud de onda efectiva                             |
| $\mu_B(\lambda)A$ | coeficiente de absorci6n de masa del elemento B a la longitud de onda caracterfstica del elemento A                  |
| $\mu_A(\lambda)A$ | coeficiente de absorci6n de masa del elemento A a su longitud de onda caracterfstica                                 |
| A                 | factor geom6trico del espectr6metro (1.5)  |

de onda efectiva, que es aproximadamente dos tercios de la longitud correspondiente a la arista de absorci6n. M6s a6n, al considerar al factor alfa como 6nico responsable o cuando menos responsable principal del efecto interelemental, se

ignoran 6os efectos Rayleigh y Compton o de difusi6n de la radiaci6n incidente, y se atribuye la diferencia de intensidad entre las radiaciones incidente y fluorescente a la absorci6n fotoel6ctrica o al impacto de los fotones incidentes sobre los electrones en los orbitales inmediatos al n6cleo del 6tomo absorbente. Dado que es alta la energfa que mantiene a estos electrones en sus orbitales y est6 intimamente asociada al n6mero at6mico, el efecto es mayor cuando m6s pesado es el elemento y es considerablemente m6s importante que los otros efectos que afectan la medici6n.

En el modelo de Lachance-Traill (1966), la concentraci6n del elemento analizado (ecuaci6n 2) es proporcional a la intensidad de la radiaci6n caracterfstica, corregida por los

$$W_i = R_i \left( 1 + \sum_j \alpha_{ij} W_j \right) \quad (2)$$

|               |  |
|---------------|--|
| $W_i$         | fracci6n peso del elemento analizado i   |
| $R_i$         | intensidad de la radiaci6n caracterfstica medida para el elemento i, relativa a un est6ndard de referencia |
| $W_j$         | fracci6n peso del elemento interferente j  |
| $\alpha_{ij}$ | factor alfa o efecto del elemento i sobre el j   |

efectos interelementales. La ecuaci6n aplicada en geoqu6mica anal6tica permite calcular concentraciones corregidas de elementos m6s precisas que las obtenidas de las tradicionales curvas anal6ticas generales, al mismo tiempo que evitan en cierto grado el uso de muestras de referencia comparables a la roca analizada y definen un modelo m6s aceptable al c6lculo computarizado.

En la Tabla 1 se presentan los factores alfa calculados para 35 elementos de inter6s geoqu6mico, afectados por 65 elementos interferentes. Asf por ejemplo, en la columna 1, el elemento excitado es el magnesio y los interferentes Li, Be, B, etc. Debe tenerse presente que el elemento excitado se mide a una radiaci6n caracterfstica y que el coeficiente

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de absorción de masa del elemento interferente varía continuamente según la longitud de onda. Por tanto, su efecto es diferente para cada elemento excitado; y en el modelo de Lachance-Traill, la corrección depende también de la fracción peso del elemento interferente. Siendo muy amplia la variedad de rocas y minerales, así como su composición, particularmente cuando hay mineralización, el uso del factor alfa simplifica apreciablemente y produce análisis más precisos.

Varias consideraciones se derivan de la Tabla I. Así, los fundentes de litio son más convenientes que los sódicos para los componentes ligeros mayores, pero indiferentes para elementos más pesados. El oxígeno, que es un componente mayor en las rocas, tiene un efecto variable, importante en los elementos ligeros. Por ejemplo, el magnesio en dolomitas o en magnesitas requeriría una corrección mayor

por oxígeno que la que se aplicaría en una diopsida.

Algunos elementos tienen factores alfa muy altos, v. gr. zinc sobre magnesio (6.56). Afortunadamente, ésta no es una asociación geoquímica común. En cambio, el hierro que es de menor factor pero mayor concentración, implicaría una corrección apreciable cuando se analiza magnesio en rocas ultrabásicas, carbonatitas complejas, anfíbolos o piroxenas.

El níquel, normalmente en rocas de alta temperatura que contienen aluminio, magnesio, hierro y cromo, requiere las correcciones pertinentes. Al igual que bismuto, para el que la casi totalidad de las alfas son negativas.

En conclusión, el empleo del factor alfa en geoquímica analítica es muy recomendable, positivo, mejora considerablemente la precisión y rapidez del análisis pero, en cada caso, deben decidirse cuáles son las correcciones pertinentes y hasta qué grado se aplican.

Tabla 1.- Efecto del factor interelemental alfa.

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | MG                | AL     | SI     | P      | S      | CL     | K      |
| LI            | -.9071            | -.9291 | -.9465 | -.9571 | -.9648 | -.9701 | -.9789 |
| BE            | -.9071            | -.9291 | -.9465 | -.9571 | -.9648 | -.9701 | -.9789 |
| B             | -.6285            | -.7160 | -.7356 | -.8276 | -.8536 | -.8797 | -.9150 |
| C             | -.2620            | -.4395 | -.5794 | -.6638 | -.7257 | -.7679 | -.8373 |
| N             | -.2620            | -.4395 | -.5794 | -.6633 | -.7257 | -.7679 | -.8373 |
| O             | .7609             | .3450  | .0147  | -.1843 | -.3318 | -.4321 | -.5990 |
| F             | 1.3372            | .7932  | .3584  | .0955  | -.0983 | -.2315 | -.4541 |
| NA            | 3.0218            | 2.1009 | 1.3595 | .9110  | .5782  | .3507  | -.0341 |
| MG            | .0000             | 2.6740 | 1.8849 | 1.4018 | 1.0352 | .7791  | .2941  |
| AL            | .2498             | .0000  | 2.4305 | 1.8990 | 1.4911 | 1.1734 | .5913  |
| SI            | .5740             | .2683  | .0000  | 2.4868 | 2.0009 | 1.6949 | .9836  |
| P             | -.2731            | .5111  | .1927  | .0000  | 2.4097 | 2.0276 | 1.3058 |
| S             | -.0857            | -.2794 | .4583  | .1970  | .0000  | 2.7171 | 1.7598 |
| CL            | .1009             | -.1316 | -.3251 | .3672  | .1473  | .0000  | 2.0000 |
| K             | .4674             | .1728  | -.0775 | -.2294 | .5517  | .3591  | .0000  |
| CA            | .6797             | .3459  | .0611  | -.1117 | -.2435 | .5467  | .1593  |
| SC            | .6797             | .3459  | .0611  | -.1117 | -.2435 | .5467  | .1593  |
| TI            | 1.1101            | .7129  | .3669  | .1571  | -.0043 | -.1144 | .4412  |
| V             | 1.3811            | .9322  | .5412  | .3043  | .1219  | -.0024 | -.2361 |
| CR            | 1.9555            | 1.3714 | .3721  | .5690  | .3376  | .1794  | -.1104 |
| MN            | 2.3063            | 1.6520 | 1.0926 | .7531  | .4939  | .3168  | -.0075 |
| FE            | 2.8429            | 2.0730 | 1.4183 | 1.0210 | .7132  | .5112  | .1347  |
| CO            | 2.7265            | 2.0101 | 1.3909 | 1.0154 | .7273  | .5307  | .1649  |
| NI            | 4.3031            | 3.1974 | 2.2693 | 1.7060 | 1.2802 | .9833  | .4711  |
| CU            | 5.2161            | 3.3705 | 2.7615 | 2.0890 | 1.5839 | 1.2383 | .6354  |
| ZN            | 6.5616            | 4.3607 | 3.4811 | 2.6457 | 2.0233 | 1.5976 | .8706  |
| GA            | 6.5616            | 4.3607 | 3.4811 | 2.6457 | 2.0233 | 1.5976 | .8706  |
| GE            | 6.5616            | 4.3607 | 3.4811 | 2.6457 | 2.0233 | 1.5976 | .8706  |
| AS            | 1.0151            | .5945  | 4.1890 | 3.2748 | 2.5364 | 2.1152 | 1.2874 |
| SE            | .6354             | .4078  | 2.7185 | 2.2820 | 1.9354 | 1.7077 | 1.1669 |
| BR            | 1.4923            | .9700  | .5386  | 4.3371 | 3.4497 | 2.8426 | 1.7921 |

Tabla 1.- Efecto del factor interelemental alfa (continuación).

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | MG                | AL     | SI     | P      | S      | CL     | K      |
| RB            | .3542             | 1.4227 | .8948  | .5738  | 4.5686 | 3.7919 | 2.4698 |
| SR            | .1541             | 1.6833 | 1.1058 | .7576  | 5.1854 | 4.3195 | 2.3378 |
| Y             | .2386             | .8937  | .8327  | .6875  | .4697  | 2.9333 | 2.4412 |
| ZR            | .3237             | .1747  | 1.6932 | 1.2337 | .8914  | 6.8725 | 4.8229 |
| NB            | .3237             | .1747  | 1.6932 | 1.2337 | .8914  | 6.8725 | 4.8229 |
| MO            | .5228             | .3546  | .1766  | 1.6221 | 1.2218 | .9593  | 4.9176 |
| RH            | .5228             | .3546  | .1766  | 1.6221 | 1.2218 | .9593  | 4.9176 |
| PD            | .5228             | .3546  | .1766  | 1.6221 | 1.2218 | .9593  | 4.9176 |
| AG            | 1.8777            | .8346  | .5819  | .4394  | 1.9711 | 1.6313 | .9981  |
| CD            | 1.2146            | .9581  | .6773  | .5226  | .3979  | 1.6992 | 1.8525 |
| IN            | 1.2146            | .9581  | .6773  | .5226  | .3979  | 1.6992 | 1.8525 |
| SN            | 1.5145            | 1.2888 | .8942  | .7154  | .5713  | .4823  | 1.3244 |
| SB            | 1.6378            | 1.3127 | .9817  | .7927  | .6485  | .5461  | 1.1987 |
| TE            | 1.7887            | 1.4341 | 1.8821 | .8386  | .7183  | .6172  | 1.3888 |
| I             | 1.8958            | 1.5488 | 1.1763 | .9695  | .8825  | .6998  | 1.4485 |
| CS            | 1.8958            | 1.5488 | 1.1763 | .9695  | .8825  | .6998  | 1.4485 |
| BA            | 1.9965            | 1.6268 | 1.2437 | 1.2945 | 1.8969 | .9739  | 1.5433 |
| LA            | 1.9965            | 1.6268 | 1.2437 | 1.2945 | 1.8969 | .9739  | 1.5433 |
| CE            | 1.9965            | 1.6268 | 1.2437 | 1.2945 | 1.8969 | .9739  | 1.5433 |
| PR            | 1.9965            | 1.6268 | 1.2437 | 1.2945 | 1.8969 | .9739  | 1.5433 |
| GD            | 1.9965            | 1.6268 | 1.2437 | 1.2945 | 1.8969 | .9739  | 1.5433 |
| YB            | 1.9965            | 1.6268 | 1.2437 | 1.2945 | 1.8969 | .9739  | 1.5433 |
| TA            | 1.9965            | 1.6268 | 1.2437 | 1.2945 | 1.8969 | .9739  | 1.5433 |
| W             | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.5747 | 1.4118 | 2.6832 |
| RE            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.5747 | 1.4118 | 2.6832 |
| OS            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.5747 | 1.4118 | 2.6832 |
| IR            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.5747 | 1.4118 | 2.6832 |
| PT            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.5747 | 1.4118 | 2.6832 |
| AU            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.5747 | 1.4118 | 2.6832 |
| HG            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.5747 | 1.4118 | 2.6832 |
| PB            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.9954 | 1.7719 | 2.9515 |
| BI            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.9954 | 1.7719 | 2.9818 |
| TH            | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.9954 | 1.7719 | 2.9818 |
| U             | 1.9965            | 1.6268 | 1.2437 | 1.8342 | 1.9954 | 1.7719 | 2.9818 |

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | CA                | TI     | V      | CR     | MN     | FE     | CO     |
| LI            | -.9831            | -.9865 | -.9388 | -.9894 | -.9984 | -.9916 | -.9923 |
| BE            | -.9831            | -.9865 | -.9388 | -.9894 | -.9984 | -.9916 | -.9923 |
| B             | -.9316            | -.9454 | -.9523 | -.9587 | -.9632 | -.9687 | -.9715 |
| C             | -.8697            | -.8969 | -.9182 | -.9224 | -.9314 | -.9411 | -.9463 |
| N             | -.8697            | -.8969 | -.9182 | -.9224 | -.9314 | -.9411 | -.9463 |
| O             | -.6776            | -.7438 | -.7755 | -.8855 | -.8235 | -.8529 | -.8672 |
| F             | -.5598            | -.6473 | -.6912 | -.7313 | -.7686 | -.7958 | -.8153 |
| NA            | -.2186            | -.3784 | -.4472 | -.5187 | -.5692 | -.6382 | -.6661 |
| MG            | .8435             | -.1465 | -.2454 | -.3386 | -.4843 | -.5217 | -.5658 |
| AL            | .2373             | .8568  | -.8651 | -.1795 | -.2688 | -.4837 | -.4594 |
| SI            | .6118             | .3285  | .1738  | .8369  | -.8638 | -.2395 | -.3119 |
| P             | .8848             | .5642  | .3926  | .2298  | .1142  | -.8917 | -.1798 |

Tabla 1.- Efecto del factor interelemental alfa (continuación).

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | CA                | TI     | V      | CR     | MN     | FE     | CO     |
| S             | 1.2632            | .8801  | .6727  | .4751  | .3364  | .1325  | .0231  |
| CL            | 1.5488            | 1.1297 | .9319  | .6333  | .5304  | .3036  | .1327  |
| K             | 2.4236            | 1.3693 | 1.5663 | 1.2751 | 1.0714 | .3372  | .6676  |
| CA            | .0000             | 2.2347 | 1.9636 | 1.6489 | 1.4315 | 1.1333 | .9732  |
| SC            | .0000             | 2.2347 | 1.9636 | 1.6489 | 1.4315 | 1.1333 | .9732  |
| TI            | .1963             | .0000  | -.1363 | 2.1333 | 1.3445 | 1.4750 | 1.2642 |
| V             | .3736             | .1279  | .0000  | -.1211 | 2.2379 | 1.3273 | 1.5535 |
| CR            | .5193             | .2670  | .1303  | .0000  | -.0000 | 2.0910 | 1.3324 |
| MN            | -.1757            | .4327  | .2662  | .1095  | .0000  | -.1359 | 2.2354 |
| FE            | -.0595            | .6122  | .4353  | .2672  | .1499  | .0000  | -.0367 |
| CO            | -.0279            | -.1727 | .5996  | .4050  | .2693  | .0993  | .0000  |
| NI            | .2103             | .0047  | -.1056 | .5319  | .3966  | .2200  | .1191  |
| CU            | .3373             | .0932  | -.0273 | .6809  | .5165  | .3115  | .1914  |
| ZN            | .5186             | .2312  | .0840  | -.0536 | .7048  | .4673  | .3269  |
| GA            | .5186             | .2312  | .0840  | -.0536 | .7048  | .4673  | .3269  |
| GE            | .5186             | .2312  | .0840  | -.0536 | .7048  | .4673  | .3269  |
| AS            | .8751             | .5465  | .3726  | .2075  | .0915  | -.0541 | -.1380 |
| SE            | .8608             | .6670  | .4229  | .2612  | .1482  | .0019  | -.0809 |
| BR            | 1.2768            | .8606  | .6443  | .4407  | .2971  | .1199  | .0169  |
| RB            | 1.8236            | 1.2999 | 1.0294 | .7755  | .5963  | .3764  | .2482  |
| SR            | 2.1175            | 1.5812 | 1.2302 | .9484  | .7494  | .5064  | .3645  |
| Y             | 1.8471            | 1.3869 | 1.1347 | .8917  | .7219  | .5023  | .3779  |
| ZR            | 3.0496            | 2.2436 | 1.8398 | 1.4659 | 1.2012 | .8848  | .6982  |
| NB            | 3.0496            | 2.2436 | 1.8398 | 1.4659 | 1.2012 | .8848  | .6982  |
| MO            | 3.7644            | 2.8068 | 2.3291 | 1.8877 | 1.5751 | 1.2028 | .9827  |
| RH            | 3.7644            | 2.8068 | 2.3291 | 1.8877 | 1.5751 | 1.2028 | .9827  |
| PD            | 3.7644            | 2.8068 | 2.3291 | 1.8877 | 1.5751 | 1.2028 | .9827  |
| AG            | 5.4189            | 4.2085 | 3.5878 | 3.0070 | 2.5968 | 2.0963 | 1.8039 |
| CD            | .7369             | 4.2732 | 3.6592 | 3.0814 | 2.6740 | 2.1714 | 1.8794 |
| IN            | .7369             | 4.2732 | 3.6592 | 3.0814 | 2.6740 | 2.1714 | 1.8794 |
| SN            | .9644             | 5.0276 | 4.3254 | 3.6647 | 3.1933 | 2.6243 | 2.2933 |
| SB            | .8313             | .6667  | 3.6260 | 3.1125 | 2.7547 | 2.2353 | 2.0216 |
| TE            | .9656             | .7366  | .5940  | 3.3063 | 2.9264 | 2.4312 | 2.1519 |
| I             | 1.0927            | .8501  | .6989  | 3.6307 | 3.2225 | 2.6903 | 2.3901 |
| CS            | 1.0927            | .8501  | .6989  | 3.6307 | 3.2225 | 2.6903 | 2.3901 |
| BA            | 1.2361            | 1.1763 | .9924  | 3.4790 | 3.3503 | 3.0434 | 3.0611 |
| LA            | 1.2361            | 1.1763 | .9924  | 3.4790 | 3.3503 | 3.0434 | 3.0611 |
| CE            | 1.2361            | 1.1763 | .9924  | 3.4790 | 3.3503 | 3.0434 | 3.0611 |
| PR            | 1.2361            | 1.1763 | .9924  | 3.4790 | 3.3503 | 3.0434 | 3.0611 |
| GD            | 1.2361            | 1.1763 | .9924  | 3.4790 | 3.3503 | 3.0434 | 3.0611 |
| YB            | 1.2361            | 1.1763 | .9924  | 3.4790 | 3.3503 | 3.0434 | 3.0611 |
| TA            | 1.2361            | 1.1763 | .9924  | 3.4790 | 3.3503 | 3.0434 | 3.0611 |
| W             | 2.1447            | 1.3963 | 1.6434 | 1.4243 | 1.2735 | 1.0505 | .9373  |
| RE            | 2.1447            | 1.3963 | 1.6434 | 1.4243 | 1.2735 | 1.0505 | .9373  |
| OS            | 2.1447            | 1.3963 | 1.6434 | 1.4243 | 1.2735 | 1.0505 | .9373  |
| IR            | 2.1447            | 1.3963 | 1.6434 | 1.4243 | 1.2735 | 1.0505 | .9373  |
| PT            | 2.1447            | 1.3963 | 1.6434 | 1.4243 | 1.2735 | 1.0505 | .9373  |
| AU            | 2.1447            | 1.3963 | 1.6434 | 1.4243 | 1.2735 | 1.0505 | .9373  |
| HG            | 2.1447            | 1.3963 | 1.6434 | 1.4243 | 1.2735 | 1.0505 | .9373  |
| PB            | 3.5547            | 3.0446 | 2.7154 | 2.3730 | 2.1514 | 1.3151 | 1.6403 |
| BI            | 3.5936            | 3.0344 | 2.9195 | 2.5664 | 2.3296 | 1.9765 | 1.7940 |
| TH            | 3.5936            | 3.0344 | 2.9195 | 2.5664 | 2.3296 | 1.9765 | 1.7940 |
| U             | 3.5936            | 3.0344 | 2.9195 | 2.5664 | 2.3296 | 1.9765 | 1.7940 |

Tabla 1.- Efecto del factor interelemental alfa (continuación).

| INTERFERIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | NI                | CU     | ZN     | AS     | SE     | BR     | RB     |
| LI            | -.9929            | -.9929 | -.9930 | -.9928 | -.9925 | -.9925 | -.9923 |
| BE            | -.9929            | -.9929 | -.9930 | -.9928 | -.9925 | -.9925 | -.9923 |
| B             | -.9741            | -.9760 | -.9781 | -.9835 | -.9832 | -.9836 | -.9844 |
| C             | -.9520            | -.9559 | -.9601 | -.9701 | -.9690 | -.9706 | -.9733 |
| N             | -.9520            | -.9559 | -.9601 | -.9701 | -.9690 | -.9706 | -.9733 |
| O             | -.8804            | -.8902 | -.9008 | -.9322 | -.9287 | -.9336 | -.9417 |
| F             | -.8339            | -.8478 | -.8627 | -.9060 | -.8996 | -.9084 | -.9227 |
| NA            | -.6991            | -.7238 | -.7502 | -.8293 | -.8171 | -.8324 | -.8575 |
| MG            | -.6066            | -.6372 | -.6703 | -.7676 | -.7529 | -.7732 | -.8065 |
| AL            | -.5110            | -.5495 | -.5912 | -.7134 | -.6951 | -.7204 | -.7619 |
| SI            | -.3787            | -.4237 | -.4824 | -.6399 | -.6164 | -.6488 | -.7018 |
| P             | -.2595            | -.3197 | -.3843 | -.5733 | -.5453 | -.5840 | -.6473 |
| S             | -.0776            | -.1530 | -.2338 | -.4700 | -.4350 | -.4834 | -.5623 |
| CL            | .0666             | -.0202 | -.1133 | -.3858 | -.3453 | -.4012 | -.4924 |
| K             | .4973             | .3759  | .2453  | -.1370 | -.0803 | -.1537 | -.2863 |
| CA            | .7846             | .6395  | .4841  | .0290  | .0966  | .0032  | -.1494 |
| SC            | .7846             | .6395  | .4841  | .0290  | .0966  | .0032  | -.1494 |
| TI            | 1.0354            | .8921  | .7321  | .2564  | .3347  | .2329  | -.0284 |
| V             | 1.2735            | 1.0945 | .9011  | .3275  | .4191  | .3013  | .0081  |
| CR            | 1.5577            | 1.3799 | 1.1809 | .5900  | .6865  | .5593  | .2511  |
| MN            | 1.3773            | 1.6489 | 1.4021 | .6716  | .7870  | .6374  | .2797  |
| FE            | 2.2636            | 2.0312 | 1.7728 | 1.0077 | 1.1303 | .9666  | .6014  |
| CO            | -.1318            | 2.4993 | 2.1768 | 1.2237 | 1.3728 | 1.1762 | .7352  |
| NI            | .0000             | -.0736 | 2.2604 | 1.4529 | 1.5857 | 1.4046 | 1.0043 |
| CU            | .0321             | .0000  | -.0906 | 1.6042 | 1.7593 | 1.5432 | 1.1869 |
| ZN            | .1998             | .1041  | .0000  | 1.9233 | 2.1053 | 1.8527 | 1.4383 |
| GA            | .1998             | .1041  | .0000  | 1.9233 | 2.1053 | 1.8527 | 1.4383 |
| GE            | .1998             | .1041  | .0000  | 1.9233 | 2.1053 | 1.8527 | 1.4383 |
| AS            | .4553             | .3503  | .2327  | .0000  | -.0596 | 2.2755 | 1.8426 |
| SE            | -.1590            | .4313  | .3079  | .0620  | .0000  | -.0785 | 1.9724 |
| BR            | -.0786            | -.1409 | .4430  | .1584  | .0836  | .0000  | -.1445 |
| RB            | .1296             | .0400  | -.0551 | .3455  | .2727  | .1600  | .0000  |
| SR            | .2332             | .1351  | .0293  | .4553  | .3760  | .2613  | .0760  |
| Y             | .2607             | .1741  | .0767  | .5682  | .4790  | .3626  | .1725  |
| ZR            | .5269             | .3984  | .2620  | -.1365 | .6076  | .4717  | .2508  |
| NB            | .5269             | .3984  | .2620  | -.1365 | .6076  | .4717  | .2508  |
| MO            | .7811             | .6293  | .4695  | .0018  | .0703  | .6657  | .4216  |
| RH            | .7811             | .6293  | .4695  | .0018  | .0703  | .6657  | .4216  |
| PD            | .7811             | .6293  | .4695  | .0018  | .0703  | .6657  | .4216  |
| AG            | 1.5337            | 1.3315 | 1.1137 | .4755  | .5708  | .4389  | .2233  |
| CD            | 1.6085            | 1.4062 | 1.1865 | .5420  | .6391  | .5045  | .2839  |
| IN            | 1.6085            | 1.4062 | 1.1865 | .5420  | .6391  | .5045  | .2839  |
| SN            | 1.9806            | 1.7493 | 1.4982 | .7615  | .8724  | .7186  | .4665  |
| SB            | 1.7721            | 1.5382 | 1.3795 | .7653  | .8624  | .7266  | .5020  |
| TE            | 1.8882            | 1.6935 | 1.4735 | .8264  | .9231  | .7859  | .5507  |
| I             | 2.1067            | 1.8975 | 1.6610 | .9654  | 1.0748 | .9218  | .6689  |
| CS            | 2.1067            | 1.8975 | 1.6610 | .9654  | 1.0748 | .9218  | .6689  |
| BA            | 2.7091            | 2.4483 | 2.1571 | 1.3006 | 1.4335 | 1.2482 | .9424  |
| LA            | 2.7091            | 2.4483 | 2.1571 | 1.3006 | 1.4335 | 1.2482 | .9424  |
| CE            | 2.7091            | 2.4483 | 2.1571 | 1.3006 | 1.4335 | 1.2482 | .9424  |
| PR            | 2.7091            | 2.4483 | 2.1571 | 1.3006 | 1.4335 | 1.2482 | .9424  |
| GD            | 2.7091            | 2.4483 | 2.1571 | 1.3006 | 1.4335 | 1.2482 | .9424  |

Tabla 1.- Efecto del factor interelemental alfa (continuación).

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | NI                | CU     | ZN     | AS     | SE     | BR     | RB     |
| YB            | 2.7091            | 2.4483 | 2.1571 | 1.3006 | 1.4335 | 1.2482 | .9424  |
| TA            | 2.7091            | 2.4483 | 2.1571 | 1.3006 | 1.4335 | 1.2482 | .9424  |
| W             | 1.8381            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| RE            | 1.8381            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| OS            | 1.8381            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| IR            | 1.8381            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| PT            | 1.8381            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| AU            | 1.8381            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| HG            | 1.3381            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| PB            | 1.4699            | 1.3489 | 1.5997 | 1.6058 | 1.5354 | 1.3678 | 1.0909 |
| BI            | 1.6150            | 1.4884 | 1.3301 | 1.7728 | 1.6950 | 1.5164 | 1.2212 |
| TH            | 1.6150            | 1.4884 | 1.3301 | 1.7728 | 1.6950 | 1.5164 | 1.2212 |
| U             | 1.6150            | 1.4884 | 1.3301 | 1.7728 | 1.6950 | 1.5164 | 1.2212 |

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | SR                | Y      | ZR     | MO     | AG     | CD     | SN     |
| LI            | -.9921            | -.9920 | -.9915 | -.9915 | -.9892 | -.9885 | -.9873 |
| BE            | -.9921            | -.9920 | -.9915 | -.9915 | -.9892 | -.9885 | -.9873 |
| B             | -.9847            | -.9854 | -.9850 | -.9849 | -.9853 | -.9851 | -.9843 |
| C             | -.9744            | -.9777 | -.9780 | -.9776 | -.9802 | -.9803 | -.9807 |
| N             | -.9744            | -.9777 | -.9780 | -.9776 | -.9802 | -.9803 | -.9807 |
| O             | -.9450            | -.9541 | -.9554 | -.9562 | -.9649 | -.9658 | -.9676 |
| F             | -.9285            | -.9437 | -.9464 | -.9471 | -.9601 | -.9616 | -.9645 |
| NA            | -.8676            | -.9018 | -.9047 | -.9065 | -.9305 | -.9335 | -.9380 |
| MG            | -.8200            | -.8561 | -.8620 | -.8641 | -.9041 | -.9092 | -.9160 |
| AL            | -.7783            | -.8237 | -.8311 | -.8337 | -.8831 | -.8893 | -.8996 |
| SI            | -.7233            | -.7804 | -.7899 | -.7930 | -.8554 | -.8633 | -.8766 |
| P             | -.6729            | -.7410 | -.7524 | -.7561 | -.8301 | -.8394 | -.8557 |
| S             | -.5942            | -.6790 | -.6933 | -.6973 | -.7803 | -.8014 | -.8223 |
| CL            | -.5293            | -.6273 | -.6438 | -.6490 | -.7556 | -.7691 | -.7942 |
| K             | -.3336            | -.4762 | -.4994 | -.5067 | -.6564 | -.6753 | -.7116 |
| CA            | -.2110            | -.3750 | -.4026 | -.4114 | -.5300 | -.6123 | -.6561 |
| SC            | -.2110            | -.3750 | -.4026 | -.4114 | -.5300 | -.6123 | -.6561 |
| TI            | -.0885            | -.2521 | -.2771 | -.2896 | -.4803 | -.5042 | -.5505 |
| V             | -.0535            | -.2215 | -.2469 | -.2601 | -.4569 | -.4815 | -.5294 |
| CR            | .1716             | -.0439 | -.0775 | -.0931 | -.3416 | -.3723 | -.4330 |
| MN            | .1992             | -.0194 | .0532  | -.0694 | -.3224 | -.3541 | -.4155 |
| FE            | .4970             | .2151  | .1704  | .1510  | -.1706 | -.2110 | -.2336 |
| CO            | .6199             | .3094  | .2596  | .2392  | -.1122 | -.1563 | -.2400 |
| NI            | .8736             | .5193  | .4630  | .4389  | .0355  | -.0152 | -.1125 |
| CU            | 1.0419            | .6300  | .5692  | .5495  | .1132  | .0583  | -.1084 |
| ZN            | 1.2701            | .8034  | .7318  | .7104  | .2152  | .1529  | -.0137 |
| GA            | 1.2701            | .8034  | .7318  | .7104  | .2152  | .1529  | -.0137 |
| GE            | 1.2701            | .8034  | .7318  | .7104  | .2152  | .1529  | -.0137 |
| AS            | 1.6658            | 1.1635 | 1.0897 | 1.0574 | .5011  | .4315  | .2354  |
| SE            | 1.7788            | 1.2555 | 1.1726 | 1.1367 | .5397  | .4643  | .3207  |
| BR            | 2.1122            | 1.5231 | 1.4320 | 1.3926 | .7203  | .6467  | .4554  |
| RB            | -.0693            | 1.3500 | 1.7513 | 1.7353 | .0637  | .0700  | .6774  |
| SR            | .0000             | 2.0762 | 1.0000 | 1.0137 | 1.0000 | .0000  | .7017  |
| Y             | .0044             | .0000  | 2.1751 | 0.1000 | 1.2475 | 1.1376 | .0000  |

Tabla 1.- Efecto del factor interelemental alfa (continuación).

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | SR                | Y      | ZR     | MO     | AG     | CD     | SN     |
| ZR            | .1606             | .0435  | .0000  | -.1233 | 1.3744 | 1.2595 | 1.0322 |
| NB            | .1606             | .0435  | .0000  | -.1233 | 1.3744 | 1.2595 | 1.0322 |
| MO            | .3218             | .1375  | .1407  | .0000  | 1.6554 | 1.5367 | 1.2953 |
| RH            | .3218             | .1375  | .1407  | .0000  | 1.6554 | 1.5367 | 1.2953 |
| PD            | .3218             | .1375  | .1407  | .0000  | 1.6554 | 1.5367 | 1.2953 |
| AG            | .1359             | .6689  | .6026  | .4130  | .0000  | -.0514 | -.1499 |
| CD            | .1945             | -.0443 | .6739  | .4800  | .0530  | .0000  | -.1019 |
| IN            | .1945             | -.0443 | .6739  | .4800  | .0530  | .0000  | -.1019 |
| SN            | .3643             | .0908  | .0457  | .6385  | .1701  | .1120  | .0000  |
| SB            | .4101             | .1597  | .1218  | .1022  | .2544  | .1960  | .0820  |
| TE            | .4546             | .1932  | .1531  | .1332  | .3060  | .2436  | .1225  |
| I             | .5656             | .2844  | .2414  | .2199  | .3856  | .3208  | .1944  |
| CS            | .5656             | .2844  | .2414  | .2199  | .3856  | .3208  | .1944  |
| BA            | .8178             | .4802  | .4272  | .4033  | .5805  | .5017  | .3498  |
| LA            | .8178             | .4802  | .4272  | .4033  | .5805  | .5017  | .3498  |
| CE            | .8178             | .4802  | .4272  | .4033  | .5805  | .5017  | .3498  |
| PR            | .8178             | .4802  | .4272  | .4033  | .5805  | .5017  | .3498  |
| GD            | .8178             | .4802  | .4272  | .4033  | .5805  | .5017  | .3498  |
| YB            | .8178             | .4802  | .4272  | .4033  | .5805  | .5017  | .3498  |
| TA            | .8178             | .4802  | .4272  | .4033  | .5805  | .5017  | .3498  |
| W             | 3.1772            | 2.3765 | 2.2481 | 2.1955 | 1.2894 | 1.1756 | .9575  |
| RE            | 3.1772            | 2.3765 | 2.2481 | 2.1955 | 1.2894 | 1.1756 | .9575  |
| OS            | 3.1772            | 2.3765 | 2.2481 | 2.1955 | 1.2894 | 1.1756 | .9575  |
| IR            | 3.1772            | 2.3765 | 2.2481 | 2.1955 | 1.2894 | 1.1756 | .9575  |
| PT            | 3.1772            | 2.3765 | 2.2481 | 2.1955 | 1.2894 | 1.1756 | .9575  |
| AU            | 3.1772            | 2.3765 | 2.2481 | 2.1955 | 1.2894 | 1.1756 | .9575  |
| HG            | 3.1772            | 2.3765 | 2.2481 | 2.1955 | 1.2894 | 1.1756 | .9575  |
| PB            | 2.3303            | 3.2856 | 3.1425 | 3.0707 | 1.9781 | 1.8415 | 1.5762 |
| BI            | 1.0995            | 3.5639 | 3.4113 | 3.3360 | 2.1564 | 2.0087 | 1.7223 |
| TH            | 1.0995            | 3.5639 | 3.4113 | 3.3360 | 2.1564 | 2.0087 | 1.7223 |
| U             | 1.0995            | 3.5639 | 3.4113 | 3.3360 | 2.1564 | 2.0087 | 1.7223 |

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | SB                | TE     | I      | BA     | W      | PB     | BI     |
| LI            | -.9870            | -.9862 | -.9857 | -.9925 | -.9964 | -.9963 | -.9967 |
| BE            | -.9870            | -.9862 | -.9857 | -.9925 | -.9964 | -.9963 | -.9967 |
| B             | -.9841            | -.9831 | -.9826 | -.9704 | -.9884 | -.9924 | -.9929 |
| C             | -.9814            | -.9812 | -.9801 | -.9440 | -.9789 | -.9866 | -.9867 |
| N             | -.9814            | -.9812 | -.9801 | -.9440 | -.9789 | -.9866 | -.9867 |
| O             | -.9693            | -.9696 | -.9707 | -.8604 | -.9474 | -.9703 | -.9690 |
| F             | -.9668            | -.9675 | -.9691 | -.8085 | -.9275 | -.9598 | -.9555 |
| NA            | -.9417            | -.9423 | -.9454 | -.6584 | -.8687 | -.9259 | -.9185 |
| MG            | -.9227            | -.9248 | -.9289 | -.5356 | -.8266 | -.9000 | -.8911 |
| AL            | -.9068            | -.9095 | -.9147 | -.4259 | -.7848 | -.8768 | -.8655 |
| SI            | -.8857            | -.8892 | -.8957 | -.2787 | -.7273 | -.8454 | -.8306 |
| P             | -.8664            | -.8708 | -.8786 | -.1519 | -.6754 | -.8170 | -.7990 |
| S             | -.8357            | -.8412 | -.8510 | .0170  | -.5959 | -.7729 | -.7502 |
| CL            | -.8099            | -.8164 | -.8279 | .1501  | -.5325 | -.7367 | -.7106 |
| K             | -.7339            | -.7434 | -.7596 | .5453  | -.3434 | -.6300 | -.5935 |
| CA            | -.6829            | -.6943 | -.7138 | .7621  | -.2176 | -.5587 | -.5154 |
| SC            | -.6829            | -.6943 | -.7138 | .7621  | -.2176 | -.5587 | -.5154 |

Tabla 1.- Efecto del factor interelemental alfa (continuación).

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | SB                | TE     | I      | BA     | W      | PB     | BI     |
| TI            | -.5839            | -.5975 | -.6219 | -.5640 | .0859  | -.5024 | -.4107 |
| V             | -.5641            | -.5780 | -.6034 | -.5145 | .0108  | -.4842 | -.3695 |
| CR            | -.4758            | -.4935 | -.5249 | -.4442 | .1479  | -.3531 | -.2568 |
| MN            | -.4594            | -.4774 | -.5095 | -.3827 | .2764  | -.3439 | -.2062 |
| FE            | -.3432            | -.3663 | -.4063 | -.2945 | .4589  | -.1767 | -.0613 |
| CO            | -.2999            | -.3251 | -.3683 | -.2311 | .6823  | -.1066 | .0519  |
| NI            | -.1808            | -.2097 | -.2597 | -.1329 | .7014  | .0311  | .1315  |
| CU            | -.1753            | -.2027 | -.2516 | -.0452 | -.6295 | .1259  | .2122  |
| ZN            | -.0883            | -.1191 | -.1737 | -.3324 | -.5962 | .2594  | .3676  |
| GA            | -.0883            | -.1191 | -.1737 | -.3324 | -.5962 | .2594  | .3676  |
| GE            | -.0883            | -.1191 | -.1737 | -.3324 | -.5962 | .2594  | .3676  |
| AS            | .1415             | .1024  | .0336  | -.1629 | -.4867 | .4563  | -.6824 |
| SE            | .2193             | .1766  | .1024  | -.0994 | -.4559 | -.6303 | -.6602 |
| BR            | .3427             | .2947  | .2122  | .0081  | -.4005 | -.6020 | -.6332 |
| RB            | .5507             | .4983  | .4055  | .2465  | -.2877 | -.5321 | -.5641 |
| SR            | .6541             | .5960  | .4952  | .3723  | -.2261 | -.4962 | -.5292 |
| Y             | .7781             | .7154  | .6068  | .2901  | -.1918 | -.4526 | -.4953 |
| ZR            | .8769             | .8118  | .6981  | .7609  | -.0734 | -.4107 | -.4414 |
| NB            | .8769             | .8118  | .6981  | .7609  | -.0734 | -.4107 | -.4414 |
| MO            | 1.1259            | 1.0530 | .9342  | 1.0671 | -.2234 | -.3271 | -.3579 |
| RH            | 1.1259            | 1.0530 | .9342  | 1.0671 | -.2234 | -.3271 | -.3579 |
| PD            | 1.1259            | 1.0530 | .9342  | 1.0671 | -.2234 | -.3271 | -.3579 |
| AG            | 1.8298            | 1.7341 | 1.5648 | 1.8239 | .1134  | -.3663 | -.3065 |
| CD            | -.1730            | 1.8320 | 1.6583 | 1.8571 | .1501  | -.3363 | -.2776 |
| IN            | -.1730            | 1.8320 | 1.6583 | 1.8571 | .1501  | -.3363 | -.2776 |
| SN            | -.0785            | -.1123 | -.1696 | 2.2659 | .3141  | -.2419 | -.1748 |
| SB            | .0000             | -.0339 | -.0936 | -.2258 | .2432  | -.2315 | -.1861 |
| TE            | .0362             | .0000  | -.0629 | -.1944 | .2932  | -.2058 | -.1567 |
| I             | .1037             | .0661  | .0000  | -.1436 | .3912  | -.1453 | -.0926 |
| CS            | .1037             | .0661  | .0000  | -.1436 | .3912  | -.1453 | -.0926 |
| BA            | .2436             | .1978  | .1203  | .0000  | .6534  | -.0025 | .0667  |
| LA            | .2436             | .1978  | .1203  | .0000  | .6534  | -.0025 | .0667  |
| CE            | .2436             | .1978  | .1203  | .0000  | .6534  | -.0025 | .0667  |
| PR            | .2436             | .1978  | .1203  | .0000  | .6534  | -.0025 | .0667  |
| GD            | .2436             | .1978  | .1203  | .0000  | .6534  | -.0025 | .0667  |
| YB            | .2436             | .1978  | .1203  | .0000  | .6534  | -.0025 | .0667  |
| TA            | .2436             | .1978  | .1203  | .0000  | .6534  | -.0025 | .0667  |
| W             | .8054             | .7404  | .6289  | .5206  | .0000  | 1.3038 | -.3913 |
| RE            | .8054             | .7404  | .6289  | .5206  | .0000  | 1.3038 | -.3913 |
| OS            | .8054             | .7404  | .6289  | .5206  | .0000  | 1.3038 | -.3913 |
| IR            | .8054             | .7404  | .6289  | .5206  | .0000  | 1.3038 | -.3913 |
| PT            | .8054             | .7404  | .6289  | .5206  | .0000  | 1.3038 | -.3913 |
| AU            | .8054             | .7404  | .6289  | .5206  | .0000  | 1.3038 | -.3913 |
| HG            | .8054             | .7404  | .6289  | .5206  | .0000  | 1.3038 | -.3913 |
| PB            | 1.3848            | 1.3073 | 1.1673 | 1.1755 | .4031  | .0000  | -.0574 |
| BI            | 1.5183            | 1.4343 | 1.2847 | 1.1902 | .4886  | .0619  | .0000  |
| TH            | 1.5183            | 1.4343 | 1.2847 | 1.1902 | .4886  | .0619  | .0000  |
| U             | 1.5183            | 1.4343 | 1.2847 | 1.1902 | .4886  | .0619  | .0000  |



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