

FACTORES INTERELEMENTALES PARA ANALISIS GEOQUIMICO POR  
FLUORESCENCIA DE RAYOS X

Liberto de Pablo-Galán\*

## RESUMEN

Los factores interelementales alfa o de efecto de absorción de masa son calculados para 35 elementos de interés geoquímico, afectados por 65 elementos interferentes de igual interés geoquímico y abundancia. Se consideran el concepto de longitud de onda efectiva del elemento analizado y un factor geométrico del espectrómetro de 1.5. La variación sistemática del factor alfa con el número atómico define sus aplicaciones y correcciones pertinentes en geoquímica analítica.

## 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 análisis geoquímico por espectrometría de rayos x, la concentración del elemento analizado es calculada de la intensidad de la radiación característica según diferentes modelos y algoritmos (de Pablo-Galán, 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 ecuación 1 (Jenkins, 1974), que considera los coeficientes de absorción de masa de los elementos analizado e interferente a las longitudes de onda característica 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 absorción de masa del elemento interferente B a la longitud de onda efectiva $\lambda$ del elemento A |
| $\mu_A(\lambda)$  | coeficiente de absorción de masa del elemento analizado A a su longitud de onda efectiva                             |
| $\mu_B(\lambda)A$ | coeficiente de absorción de masa del elemento B a la longitud de onda característica del elemento A                  |
| $\mu_A(\lambda)A$ | coeficiente de absorción de masa del elemento A a su longitud de onda característica                                 |
| A                 | factor geométrico del espectrómetro (1.5)  |

de onda efectiva, que es aproximadamente dos tercios de la longitud correspondiente a la arista de absorción. Más aún, al considerar al factor alfa como único responsable o cuando menos responsable principal del efecto interelemental, se

ignoran los efectos Rayleigh y Compton o de difusión de la radiación incidente, y se atribuye la diferencia de intensidad entre las radiaciones incidente y fluorescente a la absorción fotoeléctrica o al impacto de los fotones incidentes sobre los electrones en los orbitales inmediatos al núcleo del átomo absorbente. Dado que es alta la energía que mantiene a estos electrones en sus orbitales y está íntimamente asociada al número atómico, el efecto es mayor cuando más pesado es el elemento y es considerablemente más importante que los otros efectos que afectan la medición.

En el modelo de Lachance-Trail (1966), la concentración del elemento analizado (ecuación 2) es proporcional a la intensidad de la radiación característica, corregida por los

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

|       |   |
|-------|---|
| $W_i$ | fracción peso del elemento analizado i  |
| $R_i$ | intensidad de la radiación característica medida para el elemento i, relativa a un estándar de referencia |
| $W_j$ | fracción peso del elemento interferente j   |

$\alpha_{ij}$  factor alfa o efecto del elemento i sobre el j

efectos interelementales. La ecuación aplicada en geoquímica analítica permite calcular concentraciones corregidas de elementos más precisas que las obtenidas de las tradicionales curvas analíticas generales, al mismo tiempo que evitan en cierto grado el uso de muestras de referencia comparables a la roca analizada y definen un modelo más aceptable al cálculo computarizado.

En la Tabla 1 se presentan los factores alfa calculados para 35 elementos de interés geoquímico, afectados por 65 elementos interferentes. Así 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 radiación característica y que el coeficiente

\*Consejo de Recursos Minerales, Dr. Navarro 176, México 7, D. F. e Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad Universitaria, México 20, D. F.



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 I.- 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 | -.7856 | -.8276 | -.8586 | -.8797 | -.9150 |
| C             | -.2620            | -.4395 | -.5794 | -.6638 | -.7257 | -.7679 | -.8373 |
| N             | -.2620            | -.4395 | -.5794 | -.6638 | -.7257 | -.7679 | -.8373 |
| O             | .7609             | .3450  | .0147  | -.1848 | -.3318 | -.4321 | -.5990 |
| F             | 1.3372            | .7932  | .3584  | .0955  | -.0988 | -.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 | .5918  |
| SI            | .5740             | .2683  | .0000  | 2.4868 | 2.0099 | 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  | .1478  | .0000  | 2.0809 |
| K             | .4674             | .1728  | -.0775 | -.2294 | .5517  | .3591  | .0000  |
| CA            | .6797             | .3459  | .0611  | -.1117 | -.2435 | .5467  | .1598  |
| SC            | .6797             | .3459  | .0611  | -.1117 | -.2435 | .5467  | .1598  |
| TI            | 1.1101            | .7129  | .3669  | .1571  | -.0043 | -.1144 | .4412  |
| V             | 1.3811            | .9322  | .5412  | .3043  | .1219  | -.0024 | -.2361 |
| CR            | 1.9555            | 1.3714 | .8721  | .5690  | .3376  | .1794  | -.1104 |
| MN            | 2.3068            | 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 | .9838  | .4711  |
| CU            | 5.2161            | 3.8705 | 2.7615 | 2.0890 | 1.5839 | 1.2383 | .6354  |
| ZN            | 6.5616            | 4.8607 | 3.4811 | 2.6457 | 2.0233 | 1.5976 | .8706  |
| GA            | 6.5616            | 4.8607 | 3.4811 | 2.6457 | 2.0233 | 1.5976 | .8706  |
| GE            | 6.5616            | 4.8607 | 3.4811 | 2.6457 | 2.0233 | 1.5976 | .8706  |
| AS            | 1.0151            | .5945  | 4.1890 | 3.2748 | 2.5364 | 2.1152 | 1.2374 |
| SE            | .6354             | .4078  | 2.7185 | 2.2820 | 1.9354 | 1.7077 | 1.1669 |
| BR            | 1.4923            | .2700  | .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            | .0542             | 1.4227 | .8940  | .5730  | 4.5606 | 3.7919 | 2.4690 |
| SR            | .1541             | 1.6833 | 1.1050 | .7576  | 5.1854 | 4.3195 | 2.3370 |
| Y             | .2386             | .0937  | .8327  | .6375  | .4697  | 2.9330 | 2.4412 |
| ZR            | .3237             | .1747  | 1.6932 | 1.2337 | .3914  | 6.0725 | 4.0229 |
| NB            | .3237             | .1747  | 1.6932 | 1.2337 | .3914  | 6.0725 | 4.0229 |
| MO            | .5220             | .3546  | .1766  | 1.6221 | 1.2210 | .9593  | 4.9176 |
| RH            | .5220             | .3546  | .1766  | 1.6221 | 1.2210 | .9593  | 4.9176 |
| PD            | .5220             | .3546  | .1766  | 1.6221 | 1.2210 | .9593  | 4.9176 |
| AG            | 1.0777            | .8346  | .5819  | .4394  | 1.9711 | 1.6313 | .9901  |
| CD            | 1.2146            | .9501  | .6773  | .5226  | .3979  | 1.6992 | 1.0525 |
| IN            | 1.2146            | .9501  | .6773  | .5226  | .3979  | 1.6992 | 1.0525 |
| SN            | 1.5145            | 1.2080 | .8942  | .7154  | .5713  | .4323  | 1.3244 |
| SB            | 1.6370            | 1.3127 | .9817  | .7927  | .6405  | .5461  | 1.1987 |
| TE            | 1.7807            | 1.4341 | 1.0821 | .8306  | .7183  | .6172  | 1.3008 |
| I             | 1.8958            | 1.5400 | 1.1768 | .9695  | .8025  | .6990  | 1.4485 |
| CS            | 1.8958            | 1.5400 | 1.1768 | .9695  | .8025  | .6990  | 1.4485 |
| BA            | 1.9965            | 1.6260 | 1.2487 | 1.2945 | 1.0969 | .9739  | 1.5433 |
| LA            | 1.9965            | 1.6260 | 1.2487 | 1.2945 | 1.0969 | .9739  | 1.5433 |
| CE            | 1.9965            | 1.6260 | 1.2487 | 1.2945 | 1.0969 | .9739  | 1.5433 |
| PR            | 1.9965            | 1.6260 | 1.2487 | 1.2945 | 1.0969 | .9739  | 1.5433 |
| GD            | 1.9965            | 1.6260 | 1.2487 | 1.2945 | 1.0969 | .9739  | 1.5433 |
| YB            | 1.9965            | 1.6260 | 1.2487 | 1.2945 | 1.0969 | .9739  | 1.5433 |
| TA            | 1.9965            | 1.6260 | 1.2487 | 1.2945 | 1.0969 | .9739  | 1.5433 |
| W             | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.5747 | 1.4118 | 2.6032 |
| RE            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.5747 | 1.4118 | 2.6032 |
| OS            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.5747 | 1.4118 | 2.6032 |
| IR            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.5747 | 1.4118 | 2.6032 |
| PT            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.5747 | 1.4118 | 2.6032 |
| AU            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.5747 | 1.4118 | 2.6032 |
| HG            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.5747 | 1.4118 | 2.6032 |
| PB            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.9954 | 1.7719 | 2.9515 |
| BI            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.9954 | 1.7719 | 2.9018 |
| TH            | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.9954 | 1.7719 | 2.9018 |
| U             | 1.9965            | 1.6260 | 1.2487 | 1.3342 | 1.9954 | 1.7719 | 2.9018 |

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | CA                | TI     | V      | CR     | MN     | FE     | CO     |
| LI            | -.9831            | -.9865 | -.9880 | -.9894 | -.9904 | -.9916 | -.9923 |
| BE            | -.9831            | -.9865 | -.9880 | -.9894 | -.9904 | -.9916 | -.9923 |
| B             | -.9316            | -.9454 | -.9523 | -.9587 | -.9632 | -.9687 | -.9715 |
| C             | -.8697            | -.8969 | -.9102 | -.9224 | -.9314 | -.9411 | -.9468 |
| N             | -.8697            | -.8969 | -.9102 | -.9224 | -.9314 | -.9411 | -.9468 |
| O             | -.6776            | -.7430 | -.7755 | -.8055 | -.8285 | -.8529 | -.8672 |
| F             | -.5598            | -.6473 | -.6912 | -.7318 | -.7606 | -.7950 | -.8153 |
| NA            | -.2186            | -.3704 | -.4472 | -.5187 | -.5692 | -.6302 | -.6661 |
| MG            | .0435             | -.1465 | -.2454 | -.3386 | -.4043 | -.5217 | -.5658 |
| AL            | .2373             | .0560  | -.0651 | -.1795 | -.2600 | -.4037 | -.4594 |
| SI            | .6118             | .3285  | .1788  | .0369  | -.0630 | -.2395 | -.3119 |
| P             | .8840             | .5642  | .3926  | .2290  | .1142  | -.0917 | -.1790 |



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

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | CA                | TI     | V      | CR     | MN     | FE     | CO     |
| S             | 1.2632            | .8301  | .6727  | .4751  | .3364  | .1325  | .0231  |
| CL            | 1.5433            | 1.1297 | .9019  | .6333  | .5304  | .3036  | .1327  |
| X             | 2.4236            | 1.3693 | 1.5668 | 1.2751 | 1.0714 | .3372  | .6606  |
| CA            | .0000             | 2.2347 | 1.9636 | 1.6439 | 1.4315 | 1.1333 | .9732  |
| SC            | .0000             | 2.2347 | 1.9636 | 1.6439 | 1.4315 | 1.1333 | .9732  |
| TI            | .1963             | .0000  | -.1063 | 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 | 2.0010 | 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  | .0000  | .0000  |
| NI            | .2103             | .0047  | -.1056 | .5319  | .3966  | .2200  | .1191  |
| CU            | .3373             | .0932  | -.0273 | .6809  | .5165  | .3115  | .1914  |
| ZN            | .5186             | .2312  | .0840  | -.0536 | .7043  | .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            | 4.2035 | 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 | 2.2903 |
| 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).

| INTERFIRIENDO | 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             | .4978             | .3759  | .2453  | -.1370 | -.0803 | -.1587 | -.2868 |
| 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            | 1.8778            | 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 | 1.0048 |
| CU            | .0321             | .0000  | -.0906 | 1.6042 | 1.7598 | 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            | .4318  | .3079  | .0620  | .0000  | -.0785 | 1.9724 |
| BR            | -.0786            | -.1409 | .4430  | .1584  | .0336  | .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             | .6298  | .4695  | .0018  | .0703  | .6657  | .4216  |
| RH            | .7811             | .6298  | .4695  | .0018  | .0703  | .6657  | .4216  |
| PD            | .7811             | .6298  | .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            | 1.5832 | 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             | 1.8331            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| RE            | 1.8331            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| OS            | 1.8331            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| IR            | 1.8331            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| PT            | 1.8331            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| AU            | 1.8331            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| HG            | 1.8331            | 1.5211 | 1.2871 | .7717  | .7041  | .5611  | 3.4744 |
| PB            | 1.4699            | 1.3489 | 1.5997 | 1.6058 | 1.5354 | 1.3678 | 1.0908 |
| 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 | -.9169 |
| AL            | -.7788            | -.8237 | -.8311 | -.8337 | -.8331 | -.8393 | -.8096 |
| SI            | -.7233            | -.7304 | -.7399 | -.7930 | -.8554 | -.8633 | -.8766 |
| P             | -.6729            | -.7410 | -.7524 | -.7561 | -.8301 | -.8394 | -.8557 |
| S             | -.5942            | -.6790 | -.6933 | -.6973 | -.7303 | -.8014 | -.8223 |
| CL            | -.5293            | -.6273 | -.6438 | -.6490 | -.7556 | -.7691 | -.7942 |
| K             | -.3386            | -.4762 | -.4994 | -.5067 | -.6564 | -.6753 | -.7116 |
| CA            | -.2110            | -.3750 | -.4026 | -.4114 | -.5309 | -.6123 | -.6561 |
| SC            | -.2110            | -.3750 | -.4026 | -.4114 | -.5309 | -.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  | .0533  | -.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  | .3287  |
| BR            | 2.1122            | 1.5231 | 1.4029 | 1.3926 | .7203  | .6467  | .4554  |
| RB            | -.0693            | 1.3500 | 1.7513 | 1.7353 | .0637  | .8700  | .6774  |
| SR            | .0000             | 2.0762 | 1.0605 | 1.0137 | 1.0074 | .0050  | .7017  |
| Y             | .0044             | .0000  | 2.1751 | 0.1209 | 1.2475 | 1.1376 | .0064  |



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             | .6639  | .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 | 1.7228 |
| TH            | 1.0995            | 3.5639 | 3.4113 | 3.3360 | 2.1564 | 2.0087 | 1.7228 |
| U             | 1.0995            | 3.5639 | 3.4113 | 3.3360 | 2.1564 | 2.0087 | 1.7228 |

| INTERFIRIENDO | ELEMENTO EXCITADO |        |        |        |        |        |        |
|---------------|-------------------|--------|--------|--------|--------|--------|--------|
|               | SB                | TE     | I      | BA     | W      | PB     | BI     |
| LI            | -.9370            | -.9362 | -.9357 | -.9925 | -.9964 | -.9963 | -.9967 |
| BE            | -.9370            | -.9362 | -.9357 | -.9925 | -.9964 | -.9963 | -.9967 |
| B             | -.9341            | -.9331 | -.9326 | -.9704 | -.9384 | -.9924 | -.9929 |
| C             | -.9314            | -.9312 | -.9301 | -.9440 | -.9789 | -.9366 | -.9367 |
| N             | -.9314            | -.9312 | -.9301 | -.9440 | -.9789 | -.9366 | -.9367 |
| 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            | -.9243 | -.9239 | -.5356 | -.8266 | -.9000 | -.8911 |
| AL            | -.9068            | -.9095 | -.9147 | -.4259 | -.7348 | -.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  | -.3581 | -.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            | 1.0580 | .9342  | 1.0671 | -.2234 | -.3271 | -.3579 |
| RH            | 1.1259            | 1.0580 | .9342  | 1.0671 | -.2234 | -.3271 | -.3579 |
| PD            | 1.1259            | 1.0580 | .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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