Termos Espectroscópicos
Acoplamento *JK*

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Acoplamento *JK*

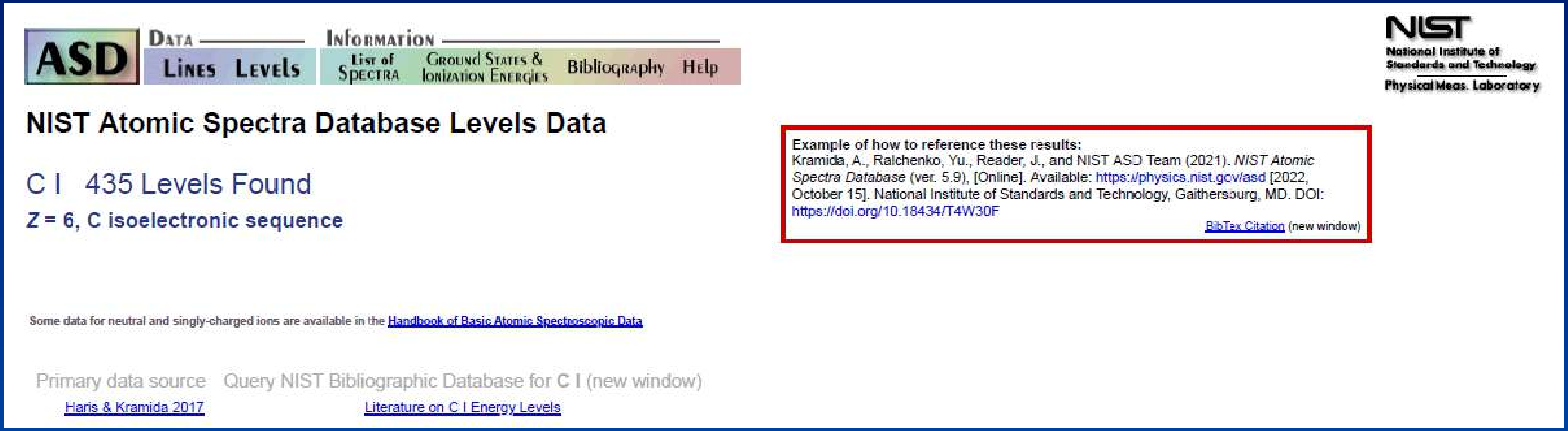
24/05/2025

Referência

- Cowan, R. D. *The theory of atomic structure and spectra*, University of California Press, 1981.

Acoplamento *JK*

Termos *JK* para o carbono


ASD
Data
Lines
Levels
Information
List of Spectra
Ground States & Ionization Energies
Bibliography
Help
NIST
National Institute of Standards and Technology
Physical Meas. Laboratory

NIST Atomic Spectra Database Levels Data

C I 435 Levels Found

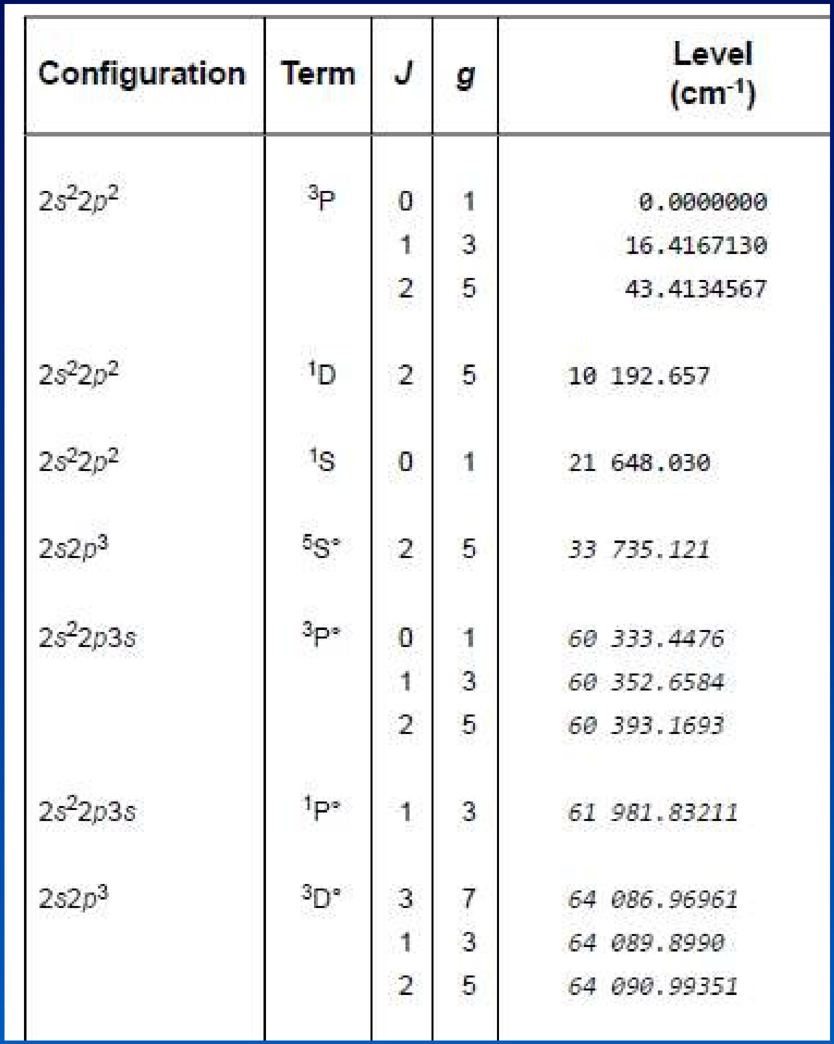
Z = 6, C isoelectronic sequence

Example of how to reference these results:
Kramida, A., Ralchenko, Yu., Reader, J., and NIST ASD Team (2021). *NIST Atomic Spectra Database* (ver. 5.9), [Online]. Available: https://physics.nist.gov/asd [2022, October 15]. National Institute of Standards and Technology, Gaithersburg, MD. DOI: https://doi.org/10.18434/T4W30F
BibTex Citation (new window)

Some data for neutral and singly-charged ions are available in the Handbook of Basic Atomic Spectroscopic Data

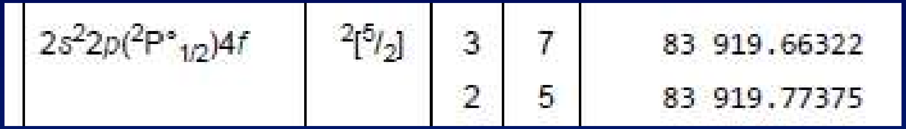
Primary data source Query NIST Bibliographic Database for **C I** (new window)
Haris & Kramida 2017 Literature on C I Energy Levels

Termos *JK* para o carbono

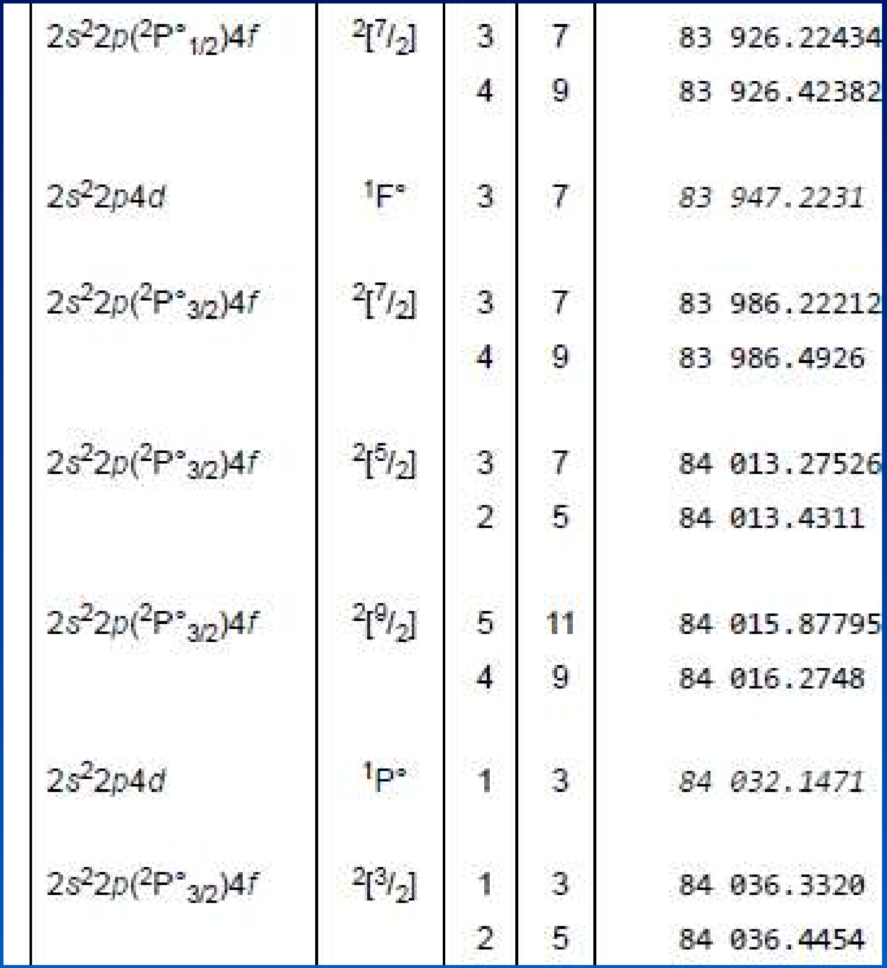


Configuration	Term	*J*	*g*	Level (cm^{-1})
$2s^22p^2$	${}^3P$	0	1	0.0000000
		1	3	16.4167130
		2	5	43.4134567
$2s^22p^2$	${}^1D$	2	5	10 192.657
$2s^22p^2$	${}^1S$	0	1	21 648.030
$2s2p^3$	${}^5S^\circ$	2	5	*33 735.121*
$2s^22p3s$	${}^3P^\circ$	0	1	*60 333.4476*
		1	3	*60 352.6584*
		2	5	*60 393.1693*
$2s^22p3s$	${}^1P^\circ$	1	3	*61 981.83211*
$2s2p^3$	${}^3D^\circ$	3	7	*64 086.96961*
		1	3	*64 089.8990*
		2	5	*64 090.99351*

Termos *JK* para o carbono

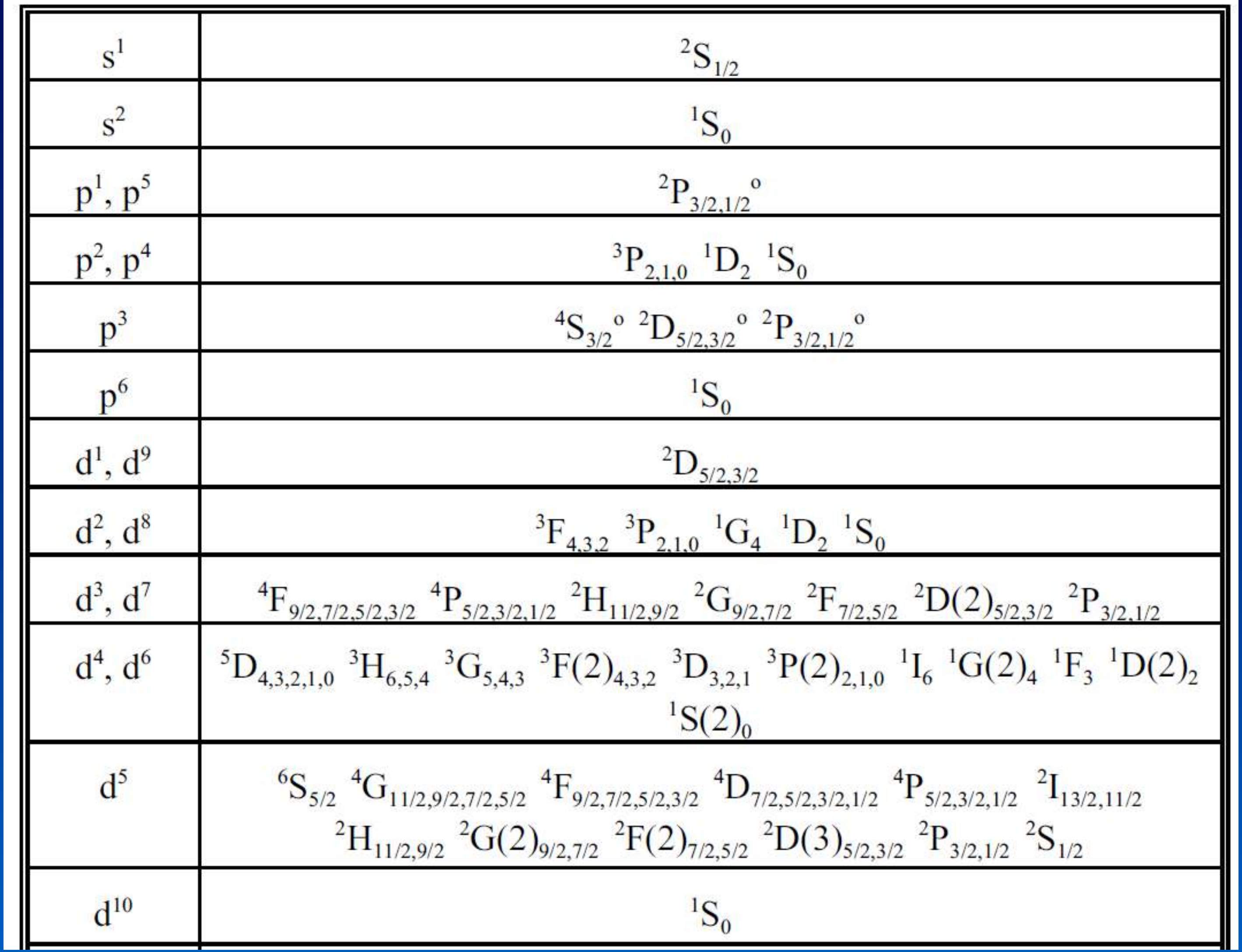


$2s^2 2p(^2P^\circ_{1/2})4f$	$^2[^5/_2]$	3	7	83 919.66322
		2	5	83 919.77375



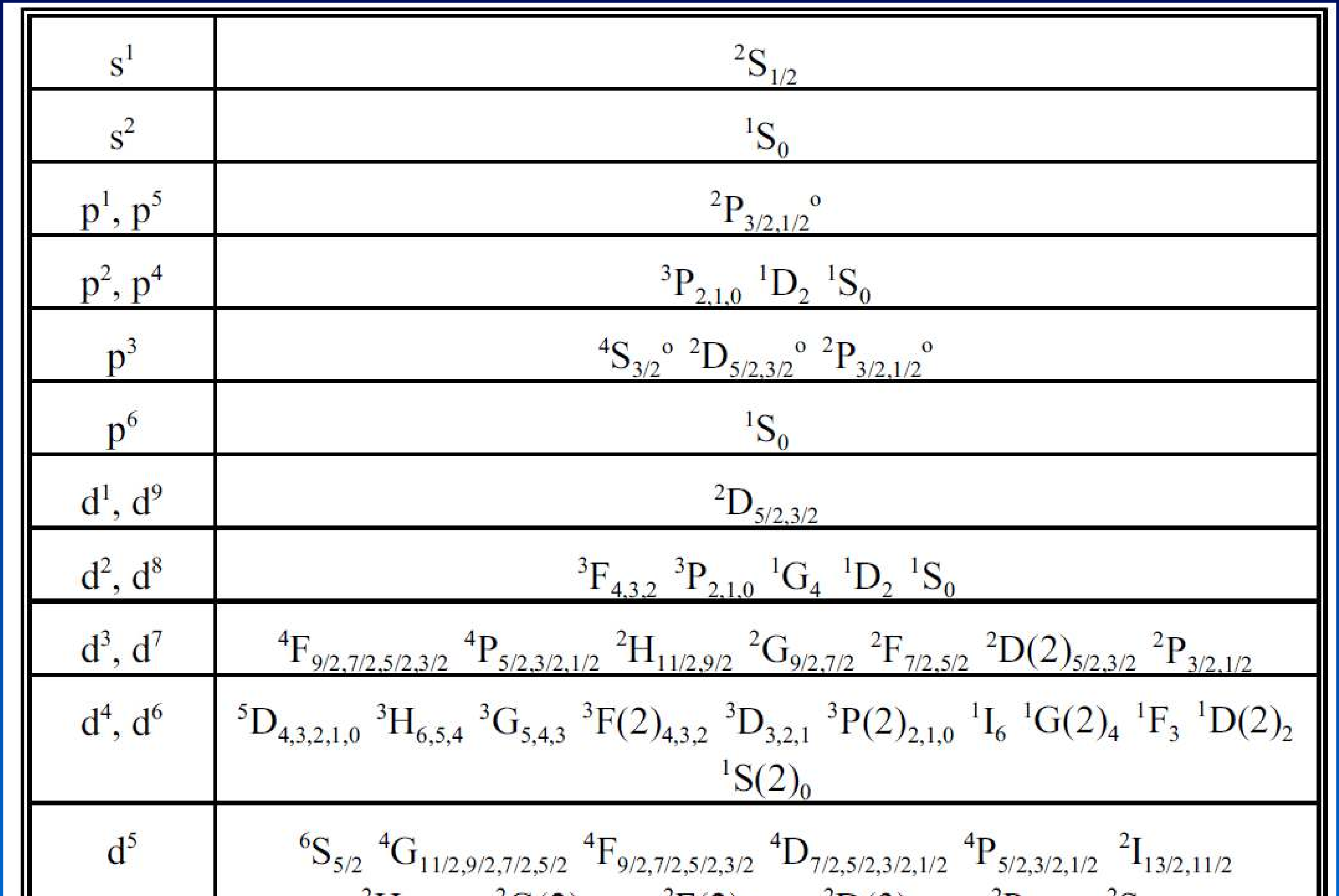
$2s^2 2p(^2P^\circ_{1/2})4f$	$^2[^7/_2]$	3	7	83 926.22434
		4	9	83 926.42382
$2s^2 2p4d$	$^1F^\circ$	3	7	*83 947.2231*
$2s^2 2p(^2P^\circ_{3/2})4f$	$^2[^7/_2]$	3	7	83 986.22212
		4	9	83 986.4926
$2s^2 2p(^2P^\circ_{3/2})4f$	$^2[^5/_2]$	3	7	84 013.27526
		2	5	84 013.4311
$2s^2 2p(^2P^\circ_{3/2})4f$	$^2[^9/_2]$	5	11	84 015.87795
		4	9	84 016.2748
$2s^2 2p4d$	$^1P^\circ$	1	3	*84 032.1471*
$2s^2 2p(^2P^\circ_{3/2})4f$	$^2[^3/_2]$	1	3	84 036.3320
		2	5	84 036.4454

Acoplamento *LS*



s^1	$^2S_{1/2}$
s^2	$^1S_0$
p^1, p^5	$^2P_{3/2,1/2}{}^{o}$
p^2, p^4	$^3P_{2,1,0}$ $^1D_2$ $^1S_0$
p^3	$^4S_{3/2}{}^{o}$ $^2D_{5/2,3/2}{}^{o}$ $^2P_{3/2,1/2}{}^{o}$
p^6	$^1S_0$
d^1, d^9	$^2D_{5/2,3/2}$
d^2, d^8	$^3F_{4,3,2}$ $^3P_{2,1,0}$ $^1G_4$ $^1D_2$ $^1S_0$
d^3, d^7	$^4F_{9/2,7/2,5/2,3/2}$ $^4P_{5/2,3/2,1/2}$ $^2H_{11/2,9/2}$ $^2G_{9/2,7/2}$ $^2F_{7/2,5/2}$ $^2D(2)_{5/2,3/2}$ $^2P_{3/2,1/2}$
d^4, d^6	$^5D_{4,3,2,1,0}$ $^3H_{6,5,4}$ $^3G_{5,4,3}$ $^3F(2)_{4,3,2}$ $^3D_{3,2,1}$ $^3P(2)_{2,1,0}$ $^1I_6$ $^1G(2)_4$ $^1F_3$ $^1D(2)_2$ $^1S(2)_0$
d^5	$^6S_{5/2}$ $^4G_{11/2,9/2,7/2,5/2}$ $^4F_{9/2,7/2,5/2,3/2}$ $^4D_{7/2,5/2,3/2,1/2}$ $^4P_{5/2,3/2,1/2}$ $^2I_{13/2,11/2}$ $^2H_{11/2,9/2}$ $^2G(2)_{9/2,7/2}$ $^2F(2)_{7/2,5/2}$ $^2D(3)_{5/2,3/2}$ $^2P_{3/2,1/2}$ $^2S_{1/2}$
d^{10}	$^1S_0$

Acoplamento *LS*



s^1	$^2S_{1/2}$
s^2	$^1S_0$
p^1, p^5	$^2P_{3/2,1/2}{}^o$
p^2, p^4	$^3P_{2,1,0}$ $^1D_2$ $^1S_0$
p^3	$^4S_{3/2}{}^o$ $^2D_{5/2,3/2}{}^o$ $^2P_{3/2,1/2}{}^o$
p^6	$^1S_0$
d^1, d^9	$^2D_{5/2,3/2}$
d^2, d^8	$^3F_{4,3,2}$ $^3P_{2,1,0}$ $^1G_4$ $^1D_2$ $^1S_0$
d^3, d^7	$^4F_{9/2,7/2,5/2,3/2}$ $^4P_{5/2,3/2,1/2}$ $^2H_{11/2,9/2}$ $^2G_{9/2,7/2}$ $^2F_{7/2,5/2}$ $^2D(2)_{5/2,3/2}$ $^2P_{3/2,1/2}$
d^4, d^6	$^5D_{4,3,2,1,0}$ $^3H_{6,5,4}$ $^3G_{5,4,3}$ $^3F(2)_{4,3,2}$ $^3D_{3,2,1}$ $^3P(2)_{2,1,0}$ $^1I_6$ $^1G(2)_4$ $^1F_3$ $^1D(2)_2$ $^1S(2)_0$
d^5	$^6S_{5/2}$ $^4G_{11/2,9/2,7/2,5/2}$ $^4F_{9/2,7/2,5/2,3/2}$ $^4D_{7/2,5/2,3/2,1/2}$ $^4P_{5/2,3/2,1/2}$ $^2I_{13/2,11/2}$

Termos *JK* para o carbono

- É usado para estados excitados envolvendo um elétron em orbitais f ou g
- Os elétrons do caroço interagem pelo acoplamento *LS*
- A interação com o elétron excitado é independente do spin
- O acoplamento *JK* considera um novo número quântico, *K*, calculado pela eq. (1).
- *J* é calculado pela eq. (2), onde $\boldsymbol{s}$ é o spin do elétron no orbital f ou g ($\boldsymbol{s}$ = ½)

$$K = J_{\text{caroço}} + \mathsf{l},\ J_{\text{caroço}} + \mathsf{l} - 1,\ J_{\text{caroço}} + \mathsf{l} - 2,\ |J_{\text{caroço}} - \mathsf{l}| \quad (1)$$

$$J = K + \boldsymbol{s},\ K + \boldsymbol{s} - 1,\ K + \boldsymbol{s} - 2,\ \ldots,\ |K - \boldsymbol{s}| \quad (2)$$

Termos *JK* para o carbono

$$^{2S+1}[\mathrm{K}]_J$$

A multiplicidade de spin considera apenas o spin do elétron mais externo (f ou g) = $2S+1 = 2(½) + 1 = 2$

Como resultado, todos os termos serão dubletos

$$^{2}[\mathrm{K}]_J$$

Termos *JK* para o carbono

$$^{2}[K]_{J}$$

Configuração eletrônica: $2s^{2}\,2p^{1}\,4f^{1}$
Termos da configuração do caroço $2s^{2}\,2p^{1}$: $^{2}P_{3/2,1/2}{}^{\circ}$
Escolhendo o termo $^{2}P_{1/2}{}^{\circ}$ ($J_{\text{caroço}} = ½$)

$$2s^{2}\,2p^{1}\,(^{2}P_{1/2}{}^{\circ})\,4f^{1}$$

$$K = J_{\text{caroço}} + l,\ J_{\text{caroço}} + l - 1,\ J_{\text{caroço}} + l - 2,\ |J_{\text{caroço}} - l| \qquad (1)$$

	0	1	2	3	4	5	6	7	8	9	10	11 ...
l (para elétrons)	s	p	d	f	g	h	i	k	l	m	n	o ...

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$$^{2}\mathrm{P}_{1/2}^{\circ}\ (J_{\mathrm{caroço}} = ½)$$

$$2s^{2}\ 2p^{1}\ (^{2}\mathrm{P}_{1/2}^{\circ})\ 4f^{1}$$

$$K = J_{\mathrm{caroço}} + l,\ J_{\mathrm{caroço}} + l - 1,\ J_{\mathrm{caroço}} + l - 2,\ |J_{\mathrm{caroço}} - l| \quad (1)$$

$$K = ½ + 3,\ |½ - 3| = 7/2,\ 5/2$$

	0	1	2	3	4	5	6	7	8	9	10	11 ...
l (para elétrons)	s	p	d	f	g	h	i	k	l	m	n	o ...

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{1/2}°)\ 4f^1$

$^{2}[7/2]_{J}$ $^{2}[5/2]_{J}$

Termos *JK* para o carbono

$$^{2}[K]_{J}$$

$2s^{2}\ 2p^{1}\ (^{2}P_{1/2}°)\ 4f^{1}$

$^{2}[7/2]_{J} \qquad ^{2}[5/2]_{J}$

Usando a Eq. (2) para calcular os valores de J

$$J = K + \mathbf{s},\ K + \mathbf{s} - 1,\ K + \mathbf{s} - 2,\ \ldots\ ,\ |K - \mathbf{s}| \qquad (2)$$

$\mathbf{s} = ½$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{1/2}°)\ 4f^1$

Para o termo $^{2}[7/2]_{J}$

$$J = K + \mathbf{s},\ K + \mathbf{s} - 1,\ K + \mathbf{s} - 2\ \ldots\ |K - \mathbf{s}| \quad (2)$$

$$J = 7/2 + ½,\ 7/2 - ½,\ = 4,\ 3$$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{1/2}°)\ 4f^1$

Obtemos os termos $^{2}[7/2]_{4,3}$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{1/2}°)\ 4f^1$

Para o termo $^{2}[5/2]_{J}$

$$J = K + \mathbf{s},\ K + \mathbf{s} - 1,\ K + \mathbf{s} - 2\ \ldots\ |K - \mathbf{s}| \quad (2)$$

$$\mathbf{s} = ½$$

$$J = 5/2 + ½,\ 5/2 - ½, = 3,\ 2$$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{1/2}°)\ 4f^1$

Obtemos os termos $^{2}[5/2]_{3,2}$

Termos *JK* para o carbono

$${}^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ ({}^2P_{1/2}{}^{\circ})\ 4f^1$

Colecionando os termos

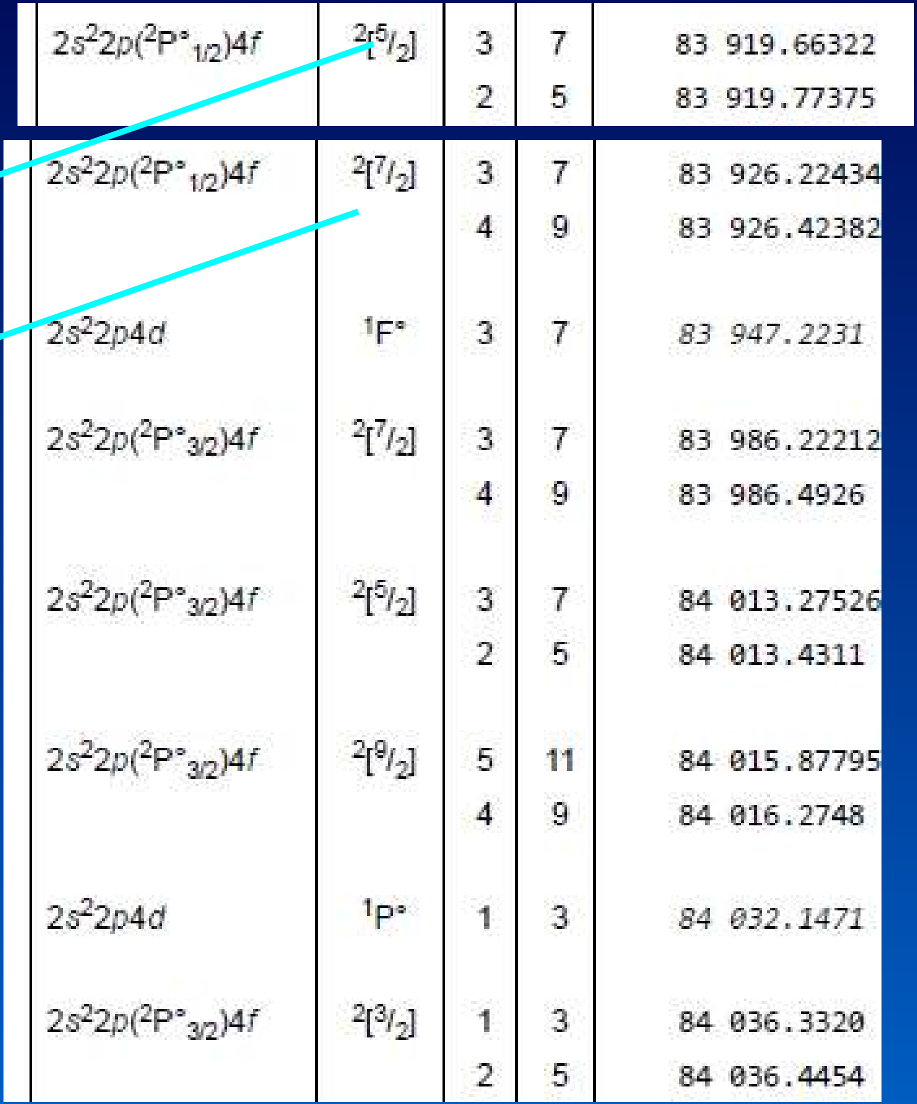
${}^{2}[7/2]_{4,3}$ ${}^{2}[5/2]_{3,2}$

Termos *JK* para o carbono

$2s^2\ 2p^1\ (^2P_{1/2}^\circ)\ 4f^1$

$^2[5/2]_{3,2}$

$^2[7/2]_{4,3}$



$2s^22p(^2P^\circ_{1/2})4f$	$^2[^5/_2]$	3	7	83 919.66322
		2	5	83 919.77375
$2s^22p(^2P^\circ_{1/2})4f$	$^2[^7/_2]$	3	7	83 926.22434
		4	9	83 926.42382
$2s^22p4d$	$^1F^\circ$	3	7	83 947.2231
$2s^22p(^2P^\circ_{3/2})4f$	$^2[^7/_2]$	3	7	83 986.22212
		4	9	83 986.4926
$2s^22p(^2P^\circ_{3/2})4f$	$^2[^5/_2]$	3	7	84 013.27526
		2	5	84 013.4311
$2s^22p(^2P^\circ_{3/2})4f$	$^2[^9/_2]$	5	11	84 015.87795
		4	9	84 016.2748
$2s^22p4d$	$^1P^\circ$	1	3	84 032.1471
$2s^22p(^2P^\circ_{3/2})4f$	$^2[^3/_2]$	1	3	84 036.3320
		2	5	84 036.4454

Termos *JK* para o carbono

$$^{2}[K]_{J}$$

Configuração eletrônica: $2s^{2}\,2p^{1}\,4f^{1}$

Termos da configuração do caroço $2s^{2}\,2p^{1}$: $^{2}P_{3/2,1/2}{}^{\circ}$

Escolhendo o termo $^{2}P_{3/2}{}^{\circ}$ ($J_{\text{caroço}} = 3/2$)

$$2s^{2}\,2p^{1}\,(^{2}P_{3/2}{}^{\circ})\,4f^{1}$$

$$K = J_{\text{caroço}} + l,\ J_{\text{caroço}} + l - 1,\ J_{\text{caroço}} + l - 2,\ |J_{\text{caroço}} - l| \qquad (1)$$

	0	1	2	3	4	5	6	7	8	9	10	11 ...
l (para elétrons)	s	p	d	f	g	h	i	k	l	m	n	o ...

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$^{2}\mathrm{P}_{3/2}°$ $(J_{\text{caroço}} = 3/2)$

$2s^{2}\,2p^{1}\,(^{2}\mathrm{P}_{3/2}°)\,4f^{1}$

$K = J_{\text{caroço}} + l,\ J_{\text{caroço}} + l - 1,\ J_{\text{caroço}} + l - 2,\ |J_{\text{caroço}} - l| \quad (1)$

$K = 3/2 + 3, \ldots\ |3/2 - 3| = 9/2,\ 7/2,\ 5/2,\ 3/2$

	0	1	2	3	4	5	6	7	8	9	10	11 ...
l (para elétrons)	s	p	d	f	g	h	i	k	l	m	n	o ...

Termos *JK* para o carbono

$$^2[\mathrm{K}]_J$$

$2s^2\ 2p^1\ (^2P_{3/2}°)\ 4f^1$

$^2[9/2]_J$ $^2[7/2]_J$ $^2[5/2]_J$ $^2[3/2]_J$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{1/2}°)\ 4f^1$

$^{2}[9/2]_{J}$ $^{2}[7/2]_{J}$ $^{2}[5/2]_{J}$ $^{2}[3/2]_{J}$

Calculando os valores de *J* pela eq. (2).

$$J = K + \mathbf{s},\ K + \mathbf{s} - 1,\ K + \mathbf{s} - 2 \ldots |K - \mathbf{s}| \quad (2)$$

$\mathbf{s} = ½$

Termos *JK* para o carbono

$$^2[K]_J$$

$$2s^2\ 2p^1\ (^2P_{1/2}°)\ 4f^1$$

Para o termo $^2[9/2]_J$

$$J = K + \mathbf{s},\ K + \mathbf{s} - 1\ ,\ K + \mathbf{s} - 2\ \ldots\ |K - \mathbf{s}| \qquad (2)$$

$$J = 9/2 + ½,\ 9/2 - ½,\ = 5,\ 4$$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{3/2}°)\ 4f^1$

Termos resultantes $^{2}[9/2]_{5,4}$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^{2}\ 2p^{1}\ (^{2}P_{3/2}°)\ 4f^{1}$

Para o termo $^{2}[7/2]_{J}$

$J = K + s, K + s - 1, K + s - 2 \ldots |K - s| \quad (2)$

$J = 7/2 + ½, 7/2 - ½, = 4, 3$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{3/2}°)\ 4f^1$

Termo resultante $^{2}[7/2]_{4,3}$

Termos *JK* para o carbono

$$^{2}[\mathrm{K}]_{J}$$

$2s^2\ 2p^1\ (^2P_{3/2}{}^\circ)\ 4f^1$

Seguindo-se o mesmo procedimento, obtemos

$^2[9/2]_{5,4}$ $^2[7/2]_{4,3}$ $^2[5/2]_{3,2}$ $^2[3/2]_{2,1}$

Termos *JK* para o carbono

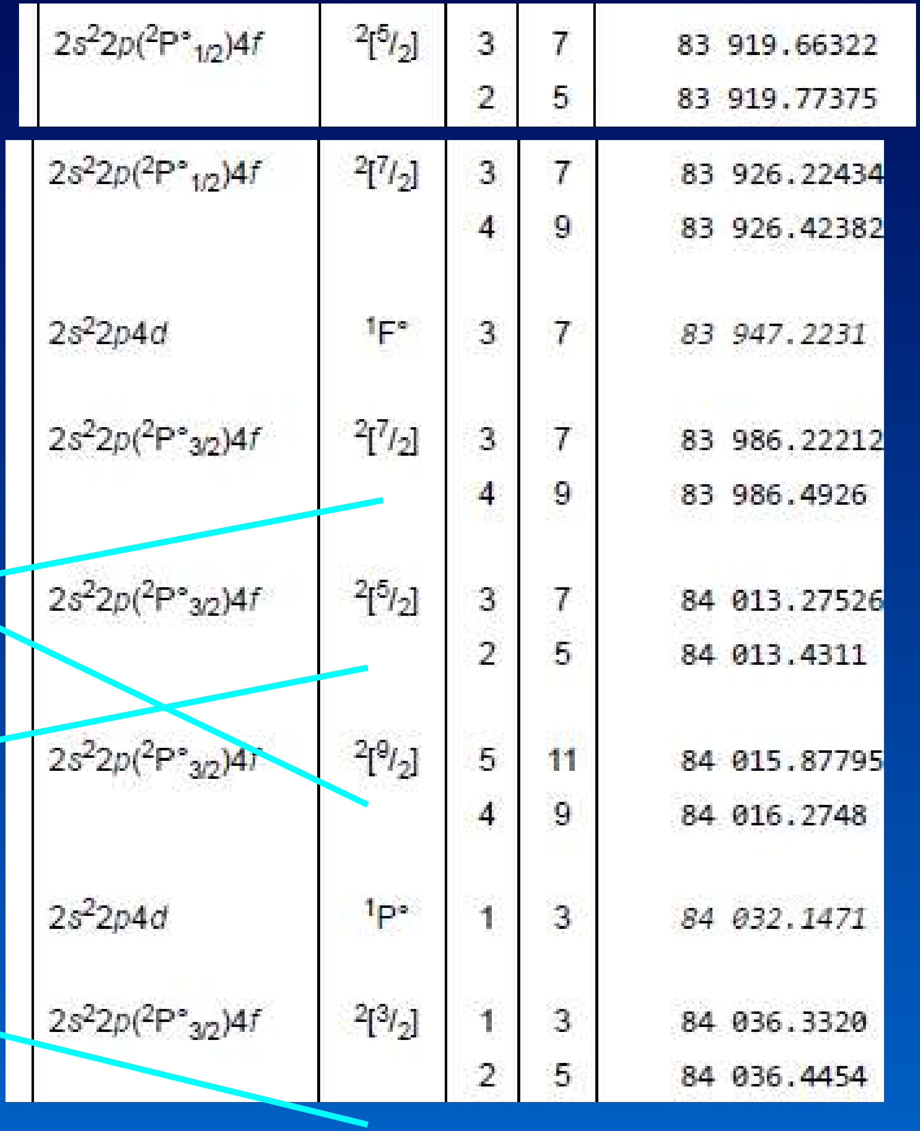
$2s^2\ 2p^1\ (^2P_{3/2}^{\circ})\ 4f^1$

$^2[9/2]_{5,4}$

$^2[7/2]_{4,3}$

$^2[5/2]_{3,2}$

$^2[3/2]_{2,1}$



$2s^22p(^2P^{\circ}_{1/2})4f$	$^2[^5/_2]$	3	7	83 919.66322
		2	5	83 919.77375
$2s^22p(^2P^{\circ}_{1/2})4f$	$^2[^7/_2]$	3	7	83 926.22434
		4	9	83 926.42382
$2s^22p4d$	$^1F^{\circ}$	3	7	*83 947.2231*
$2s^22p(^2P^{\circ}_{3/2})4f$	$^2[^7/_2]$	3	7	83 986.22212
		4	9	83 986.4926
$2s^22p(^2P^{\circ}_{3/2})4f$	$^2[^5/_2]$	3	7	84 013.27526
		2	5	84 013.4311
$2s^22p(^2P^{\circ}_{3/2})4f$	$^2[^9/_2]$	5	11	84 015.87795
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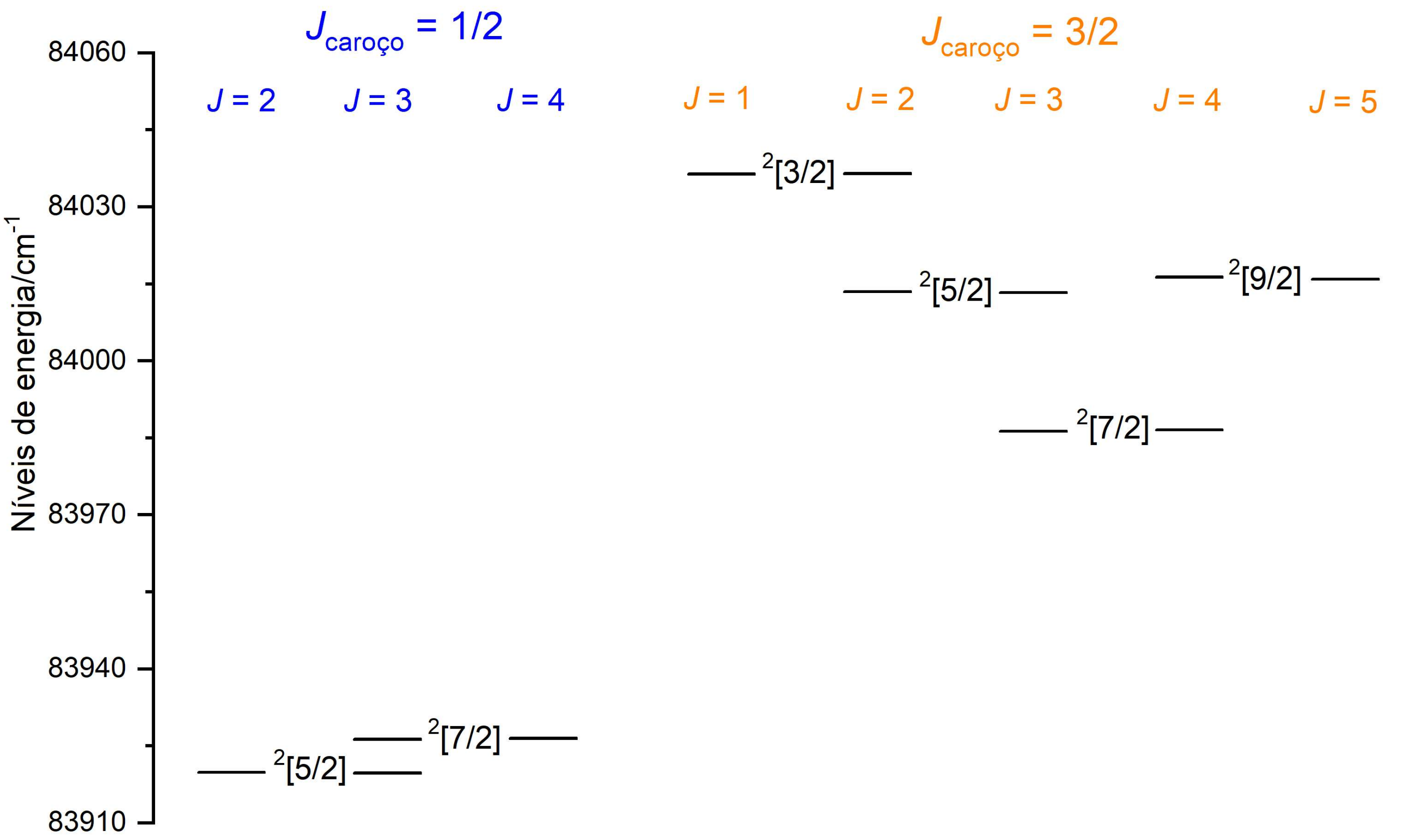
$2s^22p(^2P^{\circ}_{3/2})4f$	$^2[^3/_2]$	1	3	84 036.3320
		2	5	84 036.4454

Termos *JK* para o carbono

*Níveis de energia do carbono na configuração eletrônica $2s^2\ 2p^1\ 4f^1$



*Kramida, A.; Ralchenko, Yu.; Reader, J.; NIST ASD Team (2021) acessado em 15/10/2022

FIM