Valence Calculations of Lanthanide and Actinide Anion Binding Energies

This document contains graphical representations of our most recent relativistic configuration-interaction calculations of lanthanide and actinide anion binding energies. Our comprehensive survey of the two rows predicts 118 bound anion states for the lanthanides, La (Z=57) through Lu (Z=71), and 41 states for the actinides, Ac (Z=89) through Lr (Z=103). No bound anion states are predicted for Yb, Fm, Md, or No. This pdf file is available online (along with a color version) at:

`www.phy.mtu.edu/~donald/research.html`

The anion data is taken from the following references:

S. M. O'Malley and D. R. Beck, Phys. Rev. A **78**, 012510 (2008).
S. M. O'Malley and D. R. Beck, Phys. Rev. A **79**, 012511 (2009).
S. M. O'Malley and D. R. Beck, submitted to Phys. Rev. A (actinide work).

The neutral energies and LS designations are from the following:

Atomic Energy Levels The Rare Earth Elements, edited by W. C. Martin, R. Zalubas, and L. Hagan, Natl. Bur. Stand. Ref. Data Ser. Natl. Bur. Stand. (U.S.) Circ. No. 60 (U.S. GPO, Washington, DC, 1978).

Energy Levels and Atomic Spectra of Actinides, edited by J. Blaise and J.-F. Wyart, International Tables of Selected Constants **20**, Paris (1992).

NIST Atomic Spectra Database:
`physics.nist.gov/PhysRefData/ASD/`

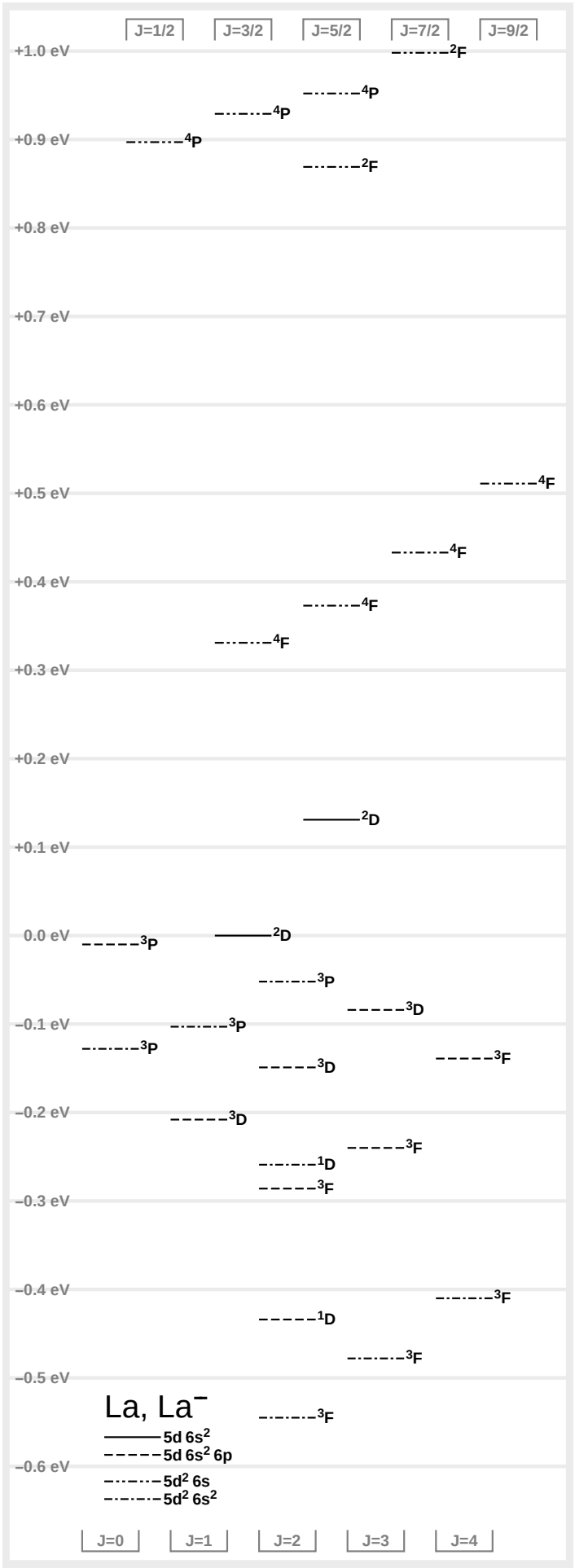
NIST Handbook of Basic Atomic Spectroscopic Data:
`physics.nist.gov/PhysRefData/Handbook/`

Neutral Lr excited ^2D thresholds are from the following computational sources:

A. Borschevsky, E. Eliav, M. J. Vilkas, Y. Ishikawa, and U. Kaldor, Eur. Phys. J. D **45**, 115 (2007).
S. Fritzsche, C. Z. Dong, F. Koike, and A. Uvarov, Eur. Phys. J. D **45**, 107 (2007).
Y. Zou and C. Froese Fischer, Phys. Rev. Lett. **88**, 183001 (2002).
E. Eliav, U. Kaldor, and Y. Ishikawa, Phys. Rev. A **52**, 291 (1995).

Please direct any inquiries to Steve O'Malley (smomalle@mtu.edu) or Don Beck (donald@mtu.edu) at:

Physics Department
Michigan Technological University
1400 Townsend Dr.
Houghton, MI 49931
Fax: 906.487.2933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^4P
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^4P
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^4F
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^3P
^3P
^3D
^3D
^3D
^3F
^3F
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^3F
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^3F
La, La⁻
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5d 6s² 6p
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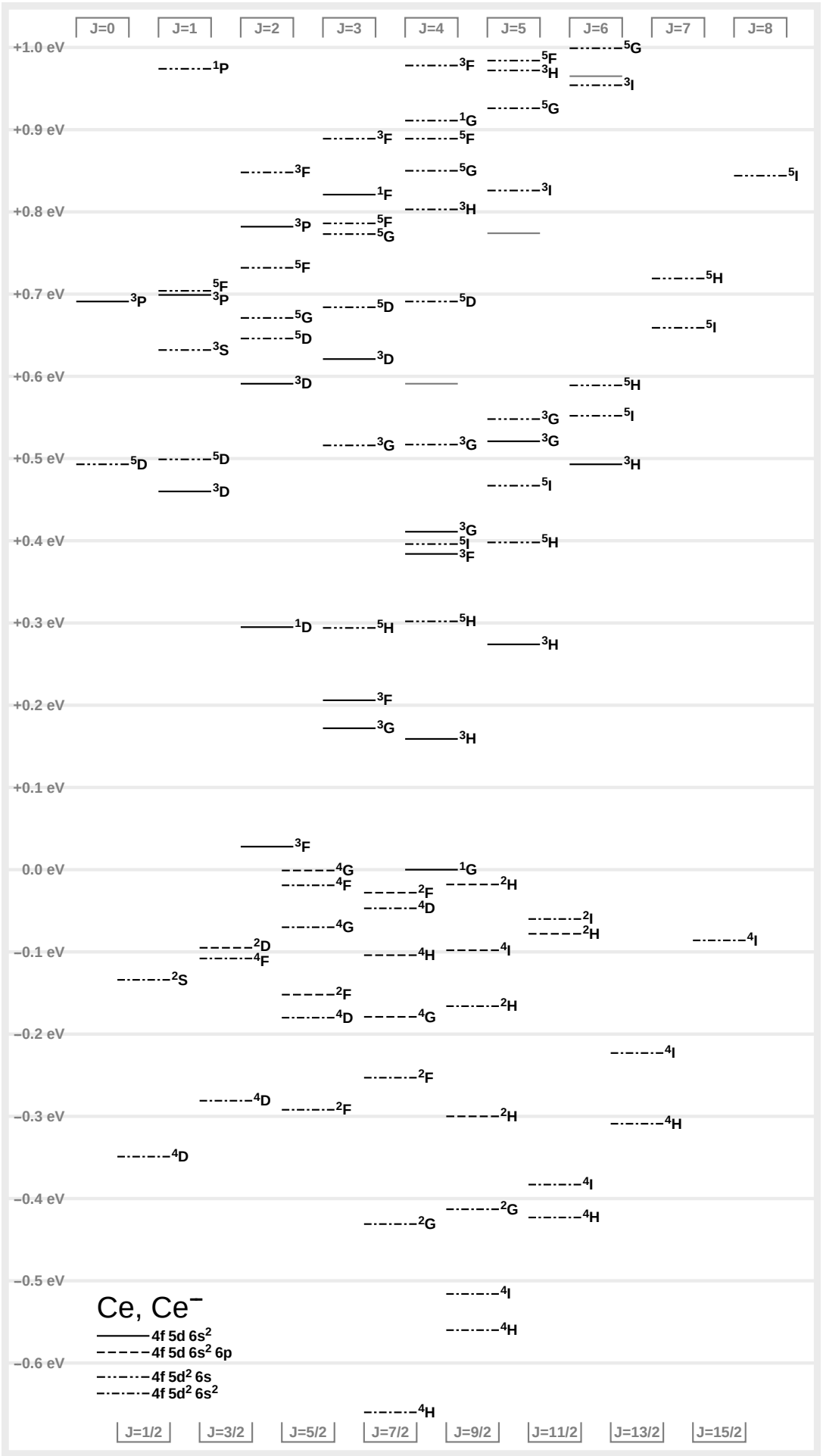
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+0.2 eV
+0.1 eV
0.0 eV
−0.1 eV
−0.2 eV
−0.3 eV
−0.4 eV
−0.5 eV
−0.6 eV
Ce, Ce⁻
4f 5d 6s²
4f 5d 6s² 6p
4f 5d² 6s
4f 5d² 6s²
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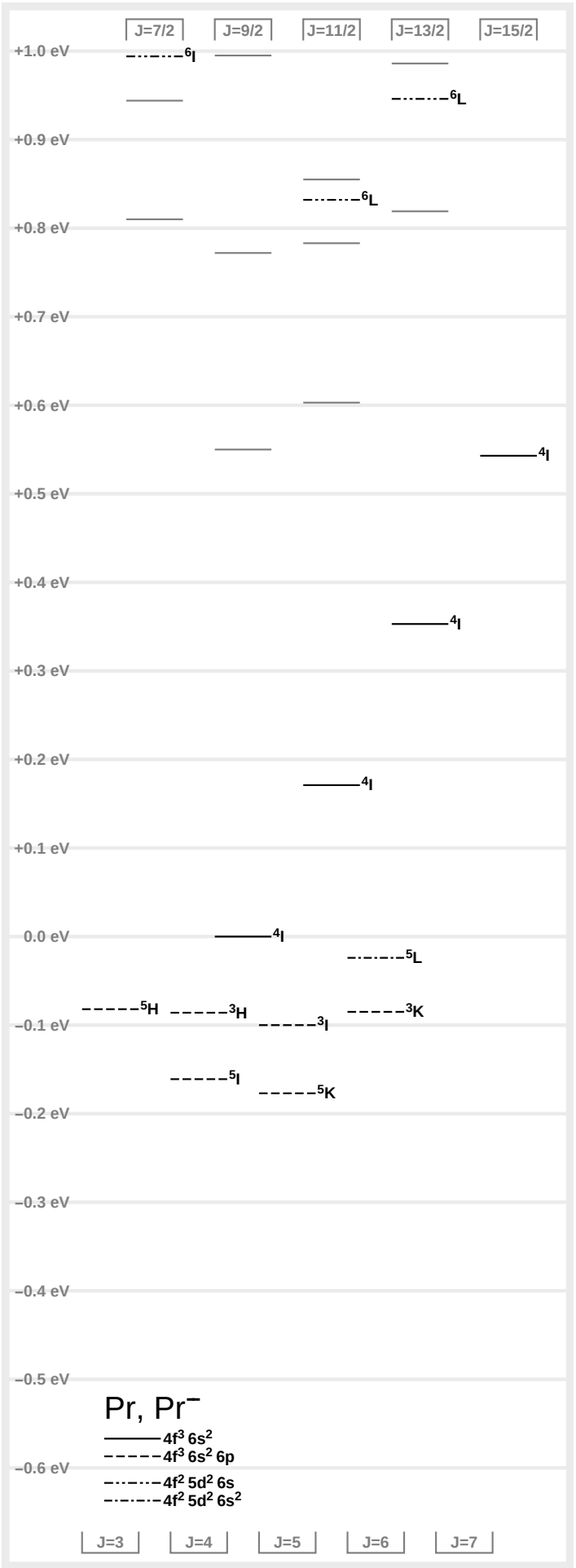
J=11/2
J=13/2
J=15/2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+0.6 eV
+0.5 eV
+0.4 eV
+0.3 eV
+0.2 eV
+0.1 eV
0.0 eV
−0.1 eV
−0.2 eV
−0.3 eV
−0.4 eV
−0.5 eV
−0.6 eV
6I
6L
6L
4I
4I
4I
4I
5L
5H
3H
3I
3K
5I
5K
Pr, Pr⁻
4f3 6s2
4f3 6s2 6p
4f2 5d2 6s
4f2 5d2 6s2
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J=5
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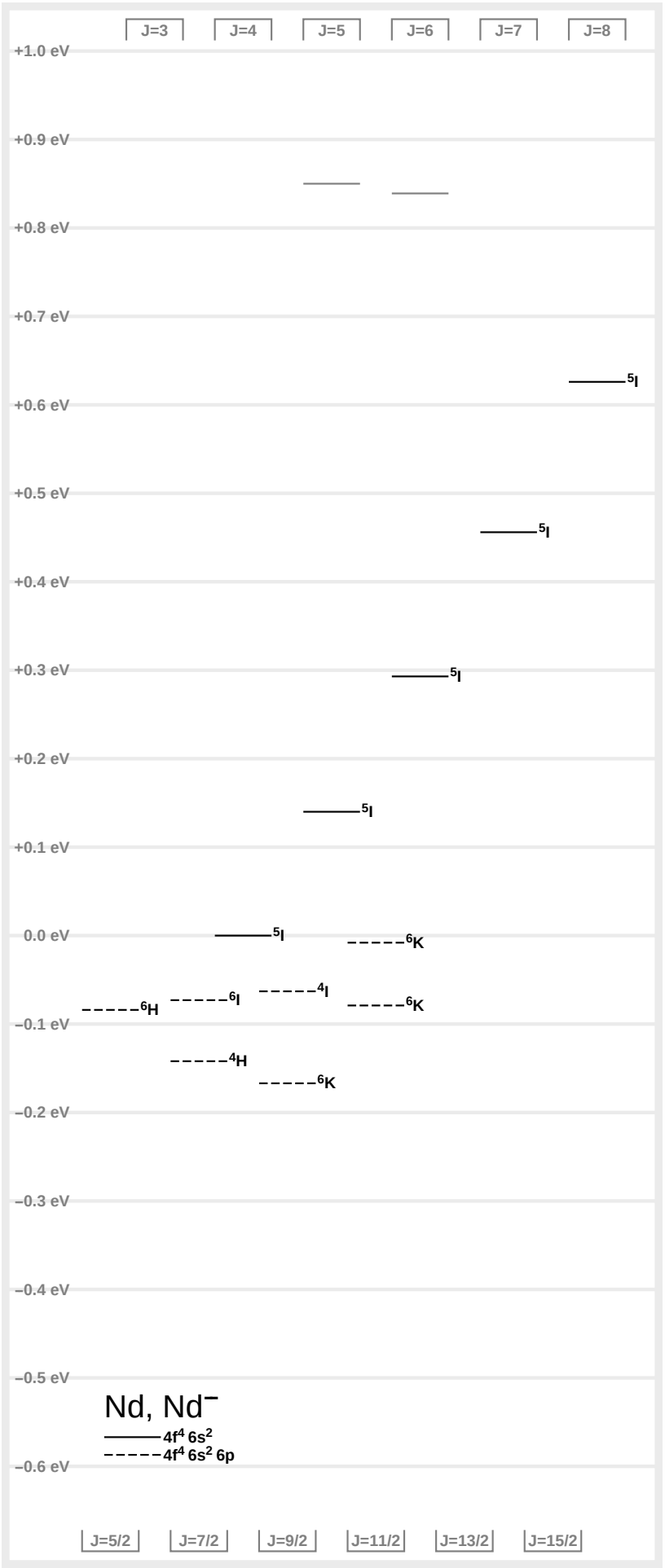
J=7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+0.3 eV
+0.2 eV
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–0.1 eV
–0.2 eV
–0.3 eV
–0.4 eV
–0.5 eV
–0.6 eV
5I
5I
5I
5I
5I
6K
6H
6I
4I
6K
4H
6K
Nd, Nd⁻
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4f4 6s2 6p
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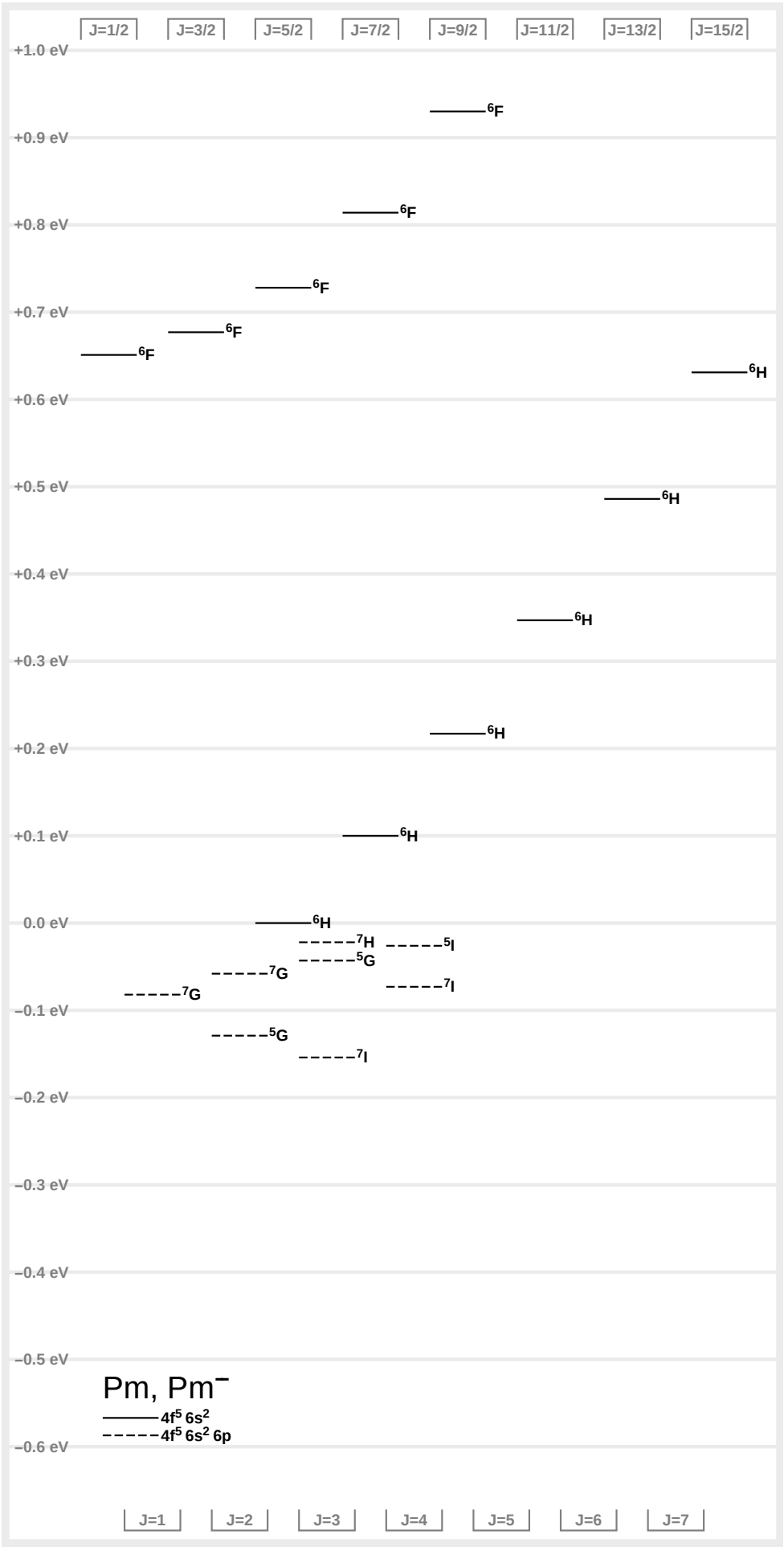
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−0.6 eV
6F
6F
6F
6F
6H
6H
6H
6H
6H
7H
5G
5I
7G
7I
7G
5G
7I
Pm, Pm⁻
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4f5 6s2 6p
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J=2
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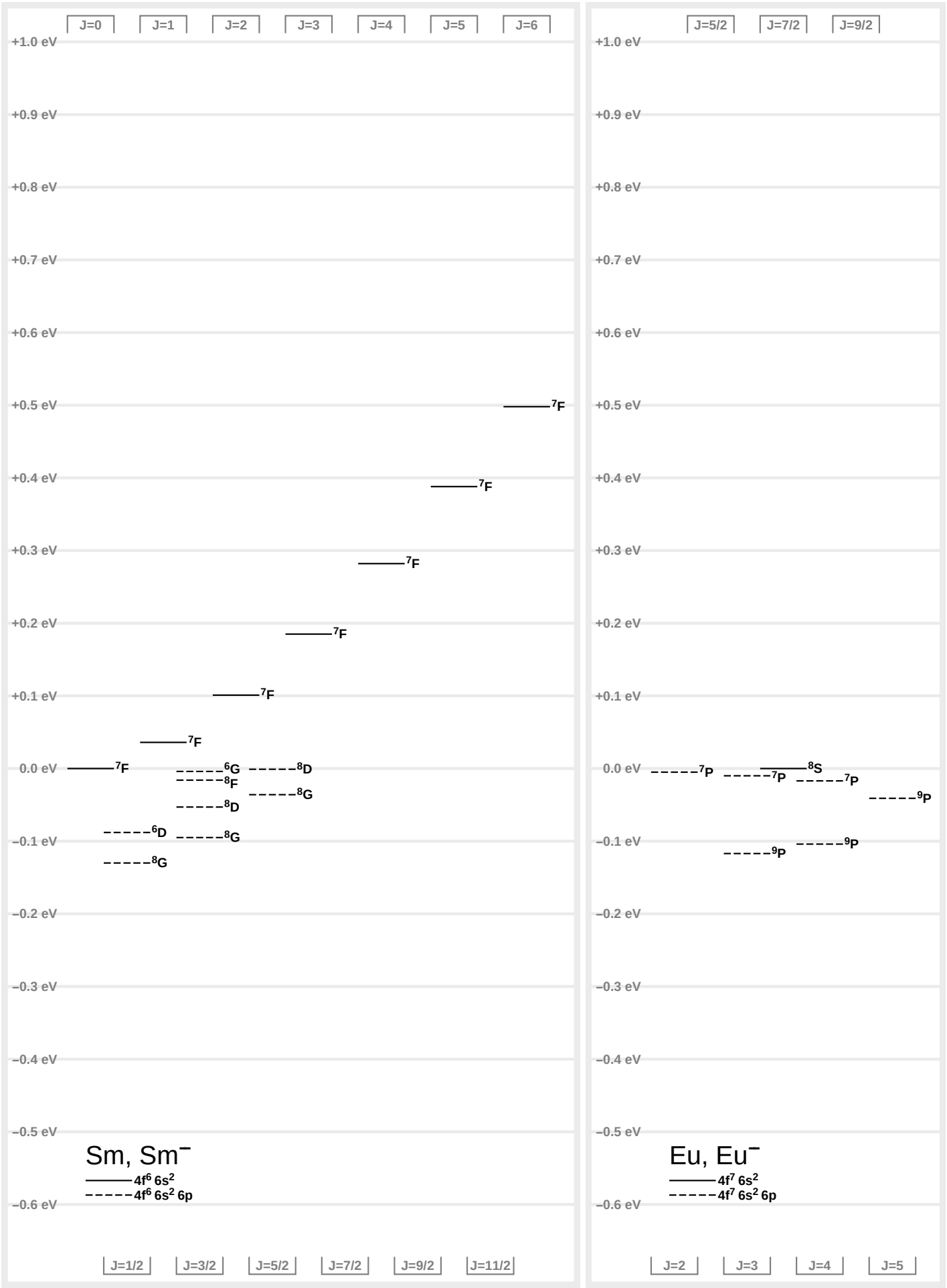
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+0.3 eV
+0.2 eV
+0.1 eV
0.0 eV
−0.1 eV
−0.2 eV
−0.3 eV
−0.4 eV
−0.5 eV
−0.6 eV
7F
7F
7F
7F
7F
7F
7F
6G
8F
8D
6D
8G
8D
8G
8G
Sm, Sm⁻
4f6 6s2
4f6 6s2 6p
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J=7/2
J=9/2
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+0.5 eV
+0.4 eV
+0.3 eV
+0.2 eV
+0.1 eV
0.0 eV
−0.1 eV
−0.2 eV
−0.3 eV
−0.4 eV
−0.5 eV
−0.6 eV
7P
7P
8S
7P
9P
9P
9P
Eu, Eu⁻
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4f7 6s2 6p
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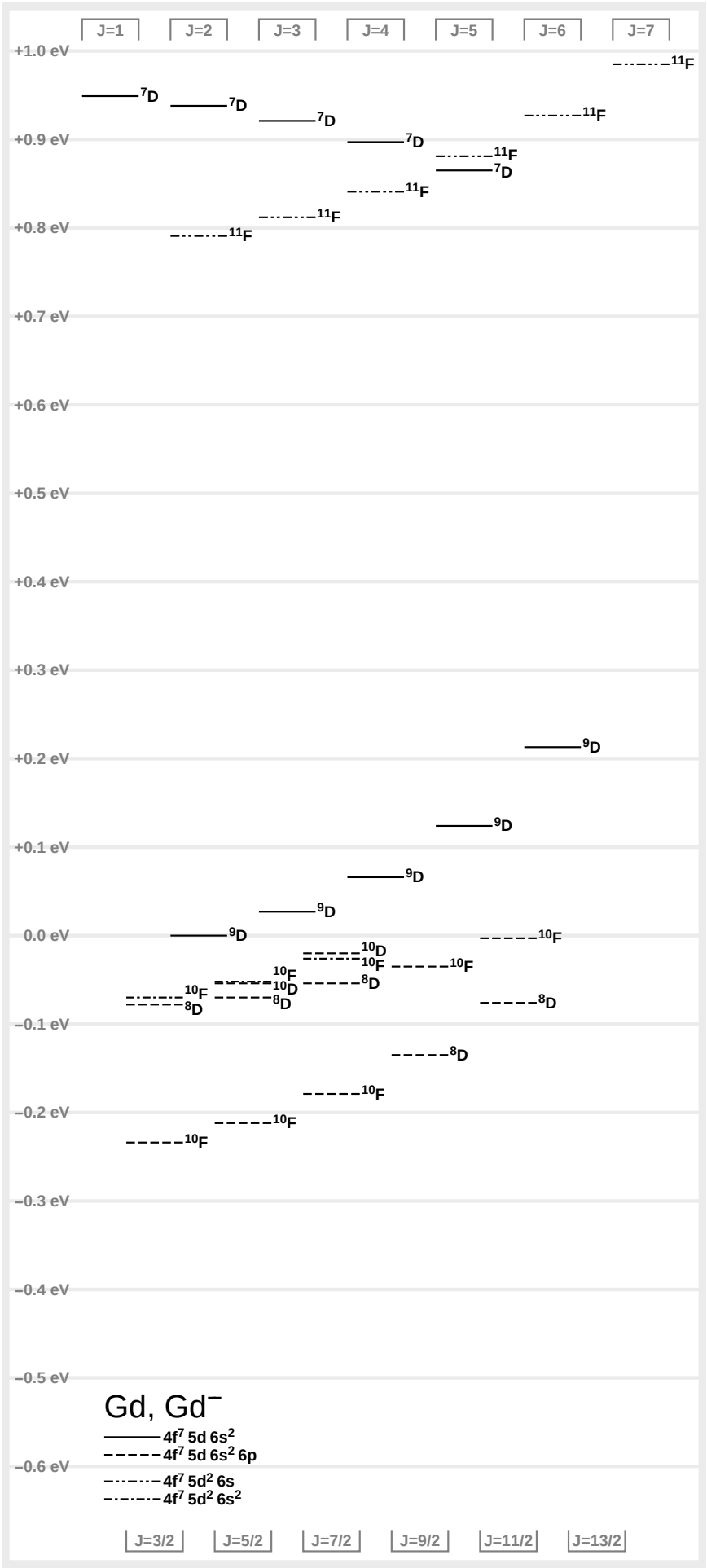
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+0.4 eV
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−0.2 eV
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−0.4 eV
−0.5 eV
−0.6 eV
7D
11F
9D
10F
10D
8D
Gd, Gd⁻
4f7 5d 6s2
4f7 5d 6s2 6p
4f7 5d2 6s
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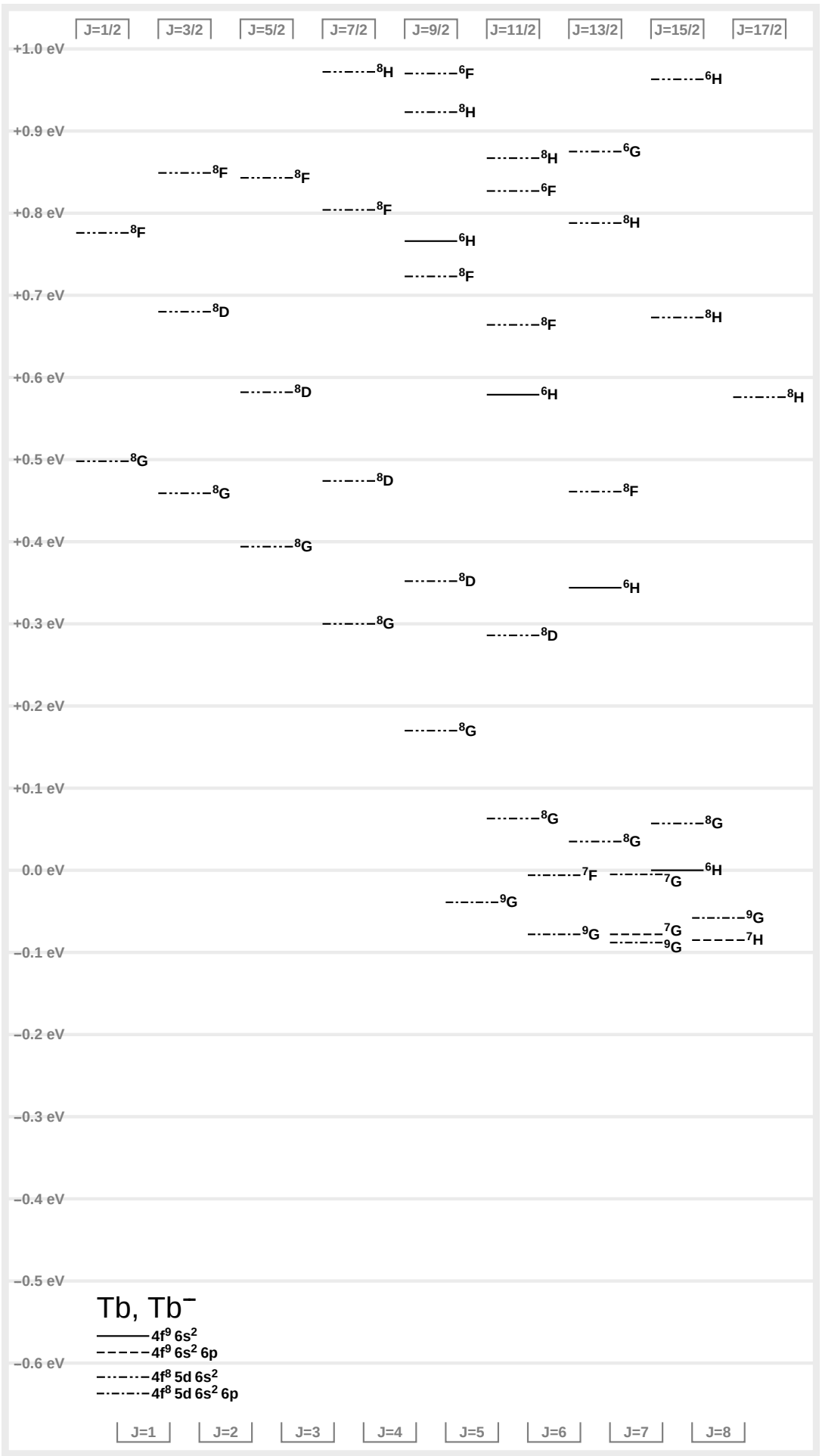
J=11/2
J=13/2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+0.7 eV
+0.6 eV
+0.5 eV
+0.4 eV
+0.3 eV
+0.2 eV
+0.1 eV
0.0 eV
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^{7}G
^{9}G
^{9}G
^{7}H
Tb, Tb$^-$
4f^9 6s^2
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4f^8 5d 6s^2
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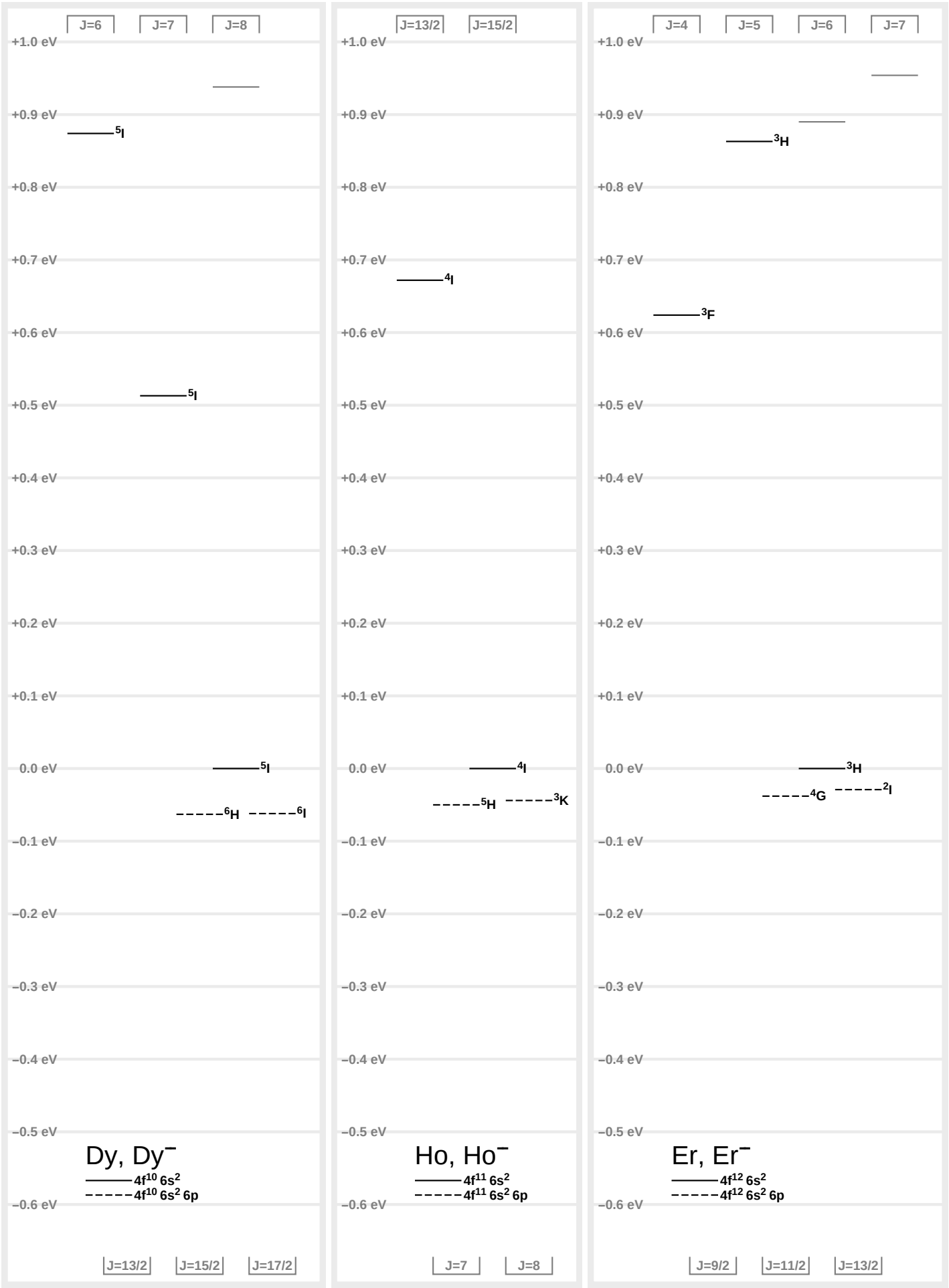
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−0.2 eV
−0.3 eV
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−0.5 eV
−0.6 eV
5I
5I
5I
6H
6I
Dy, Dy⁻
4f10 6s2
4f10 6s2 6p
J=13/2
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J=15/2
4I
4I
5H
3K
Ho, Ho⁻
4f11 6s2
4f11 6s2 6p
J=7
J=8
J=4
J=5
J=6
J=7
3H
3F
3H
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Er, Er⁻
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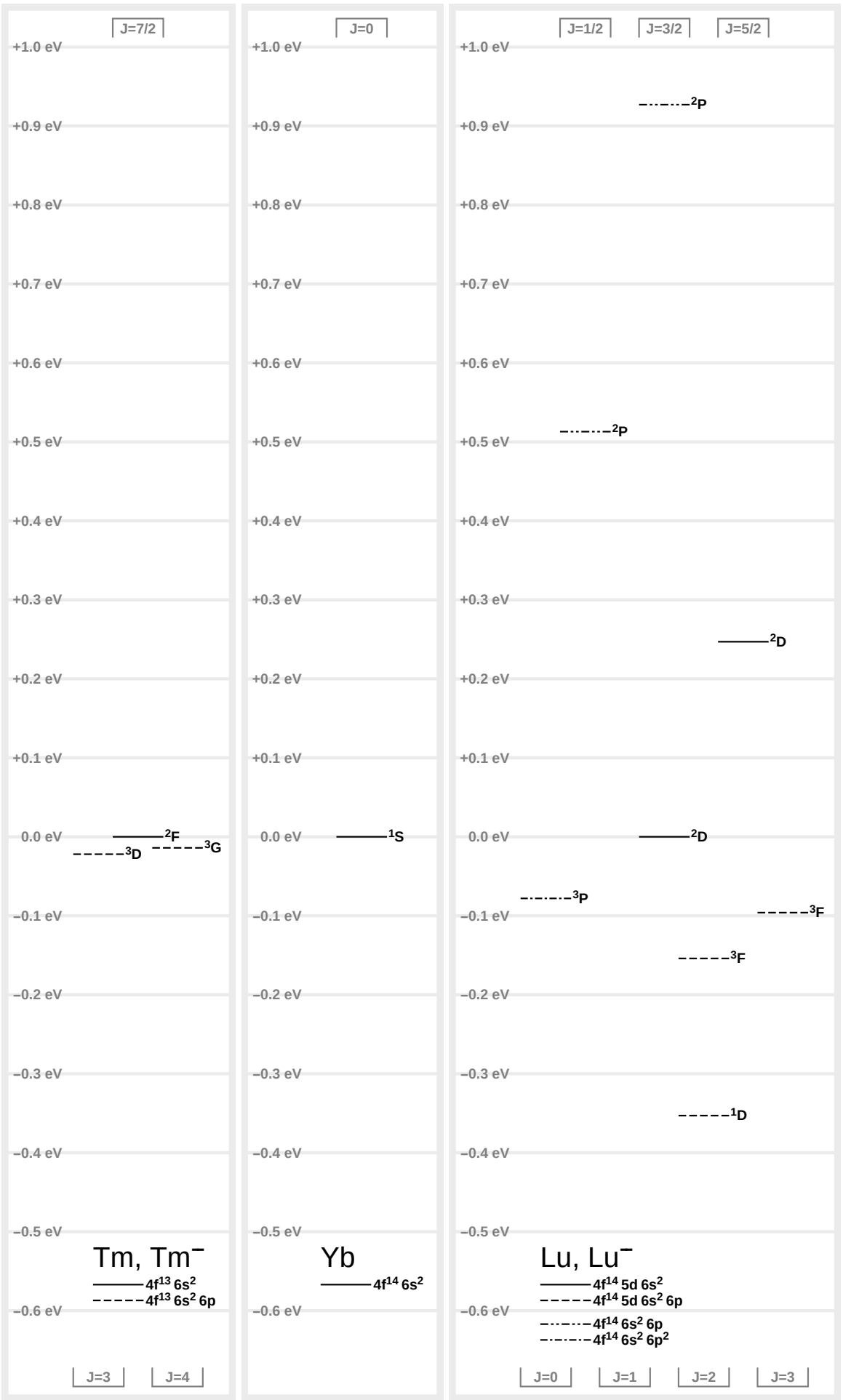
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^{1}D
Tm, Tm$^-$
4f^{13} 6s^2
4f^{13} 6s^2 6p
Yb
4f^{14} 6s^2
Lu, Lu$^-$
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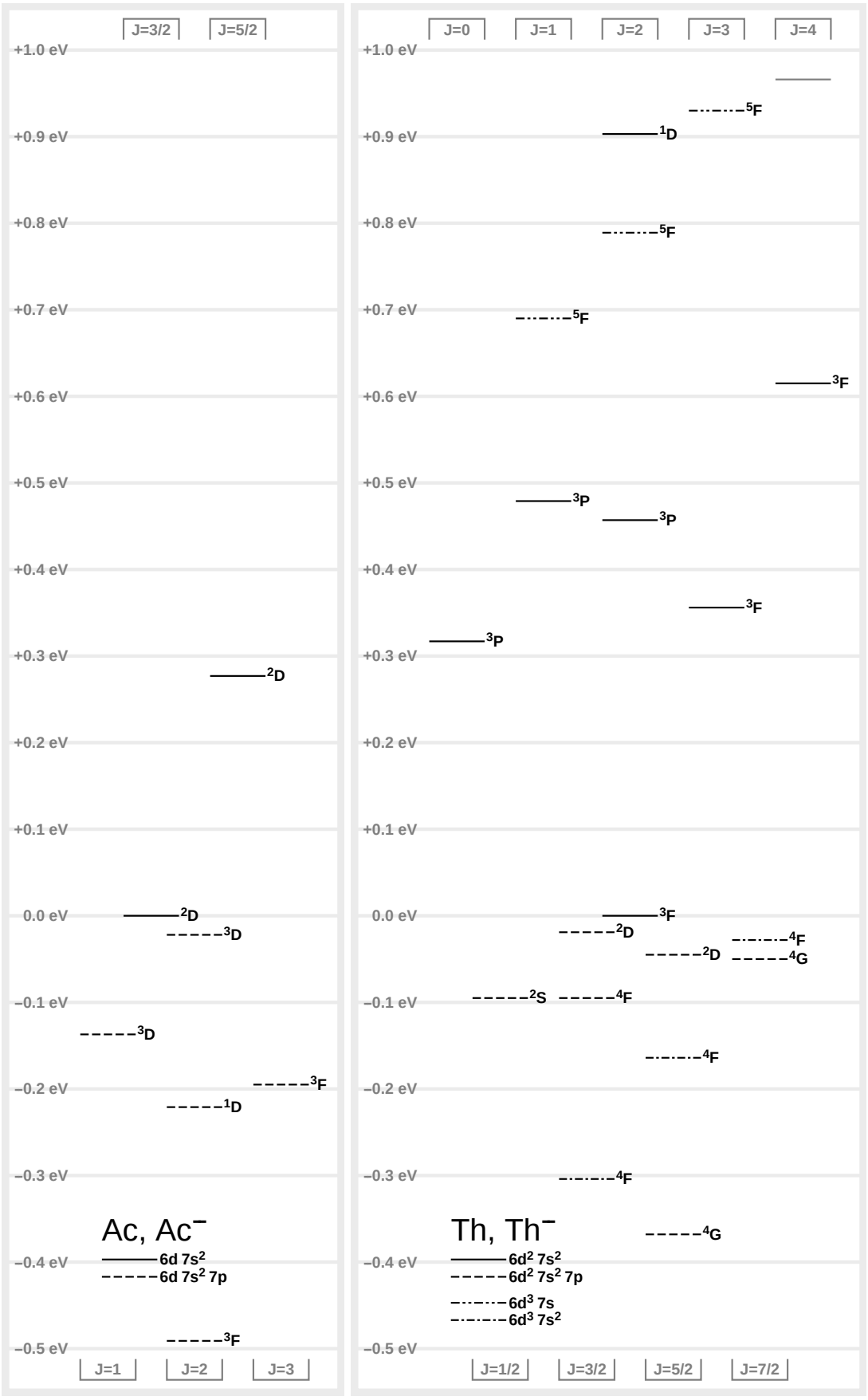
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^{3}D
^{3}F
^{1}D
^{3}F
Ac, Ac$^-$
6d 7s^2
6d 7s^2 7p
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Th, Th$^-$
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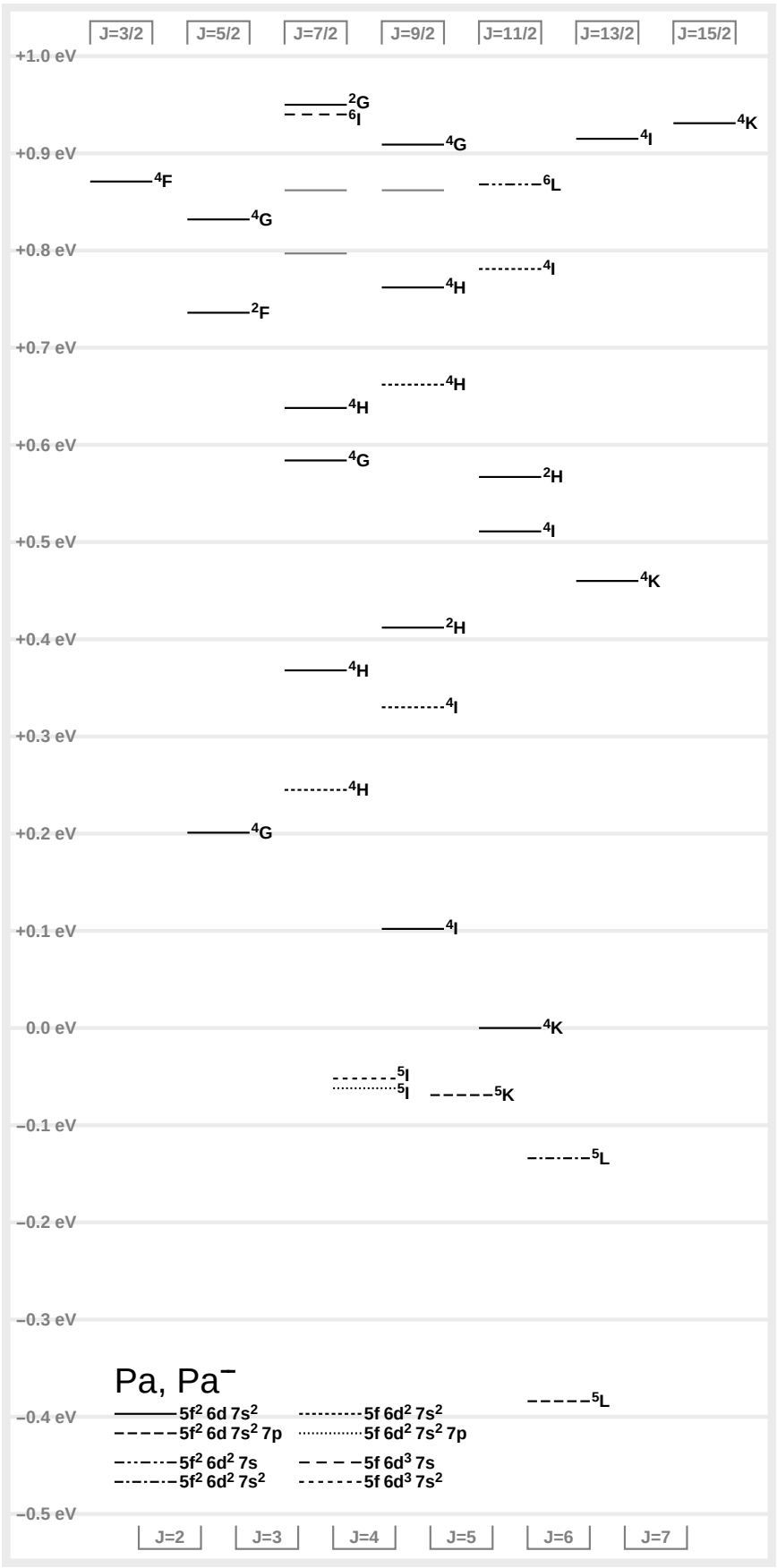
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Pa, Pa$^-$
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5f^2 6d 7s^2 7p
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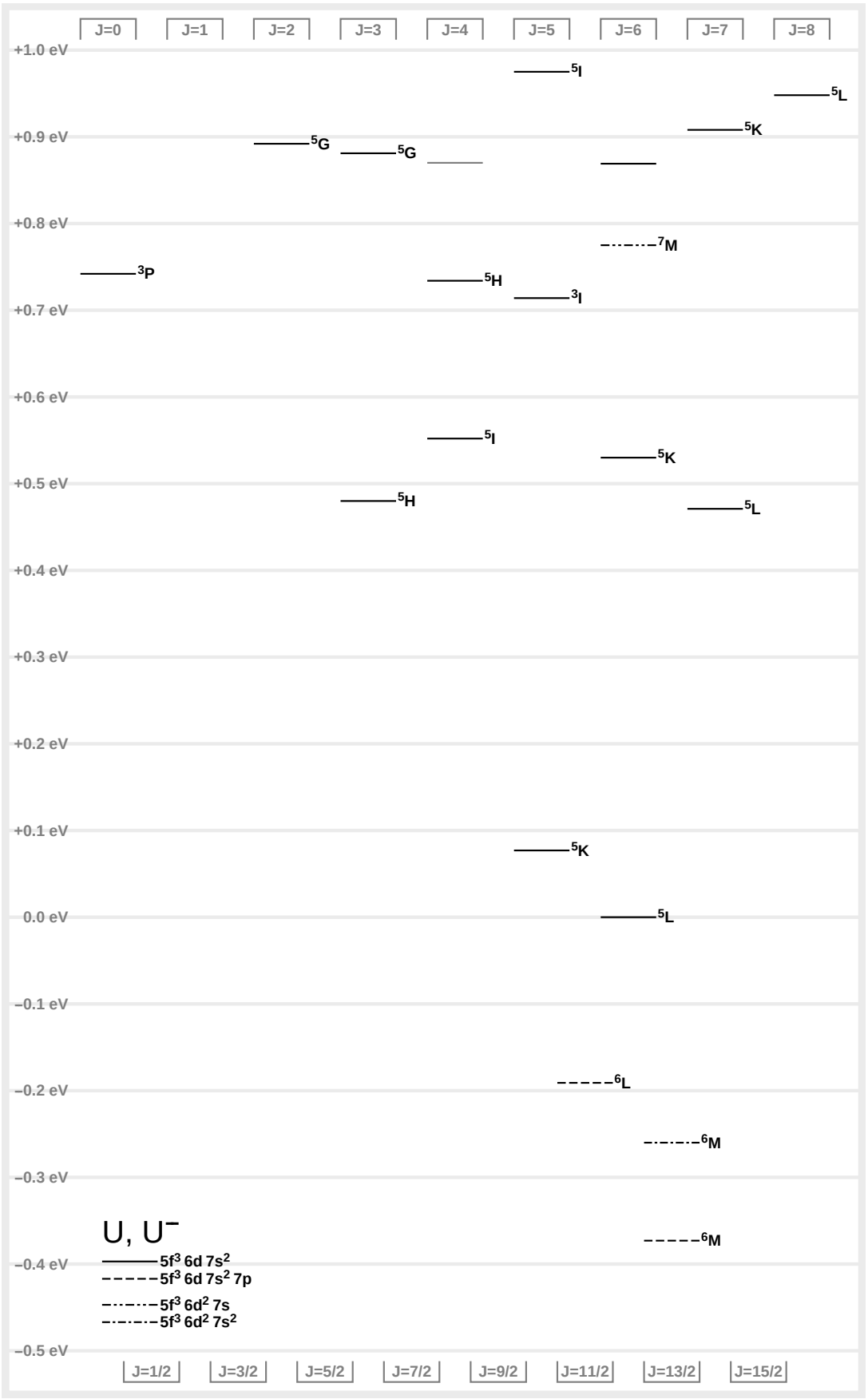
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U, U$^-$
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5f^3 6d^2 7s
5f^3 6d^2 7s^2
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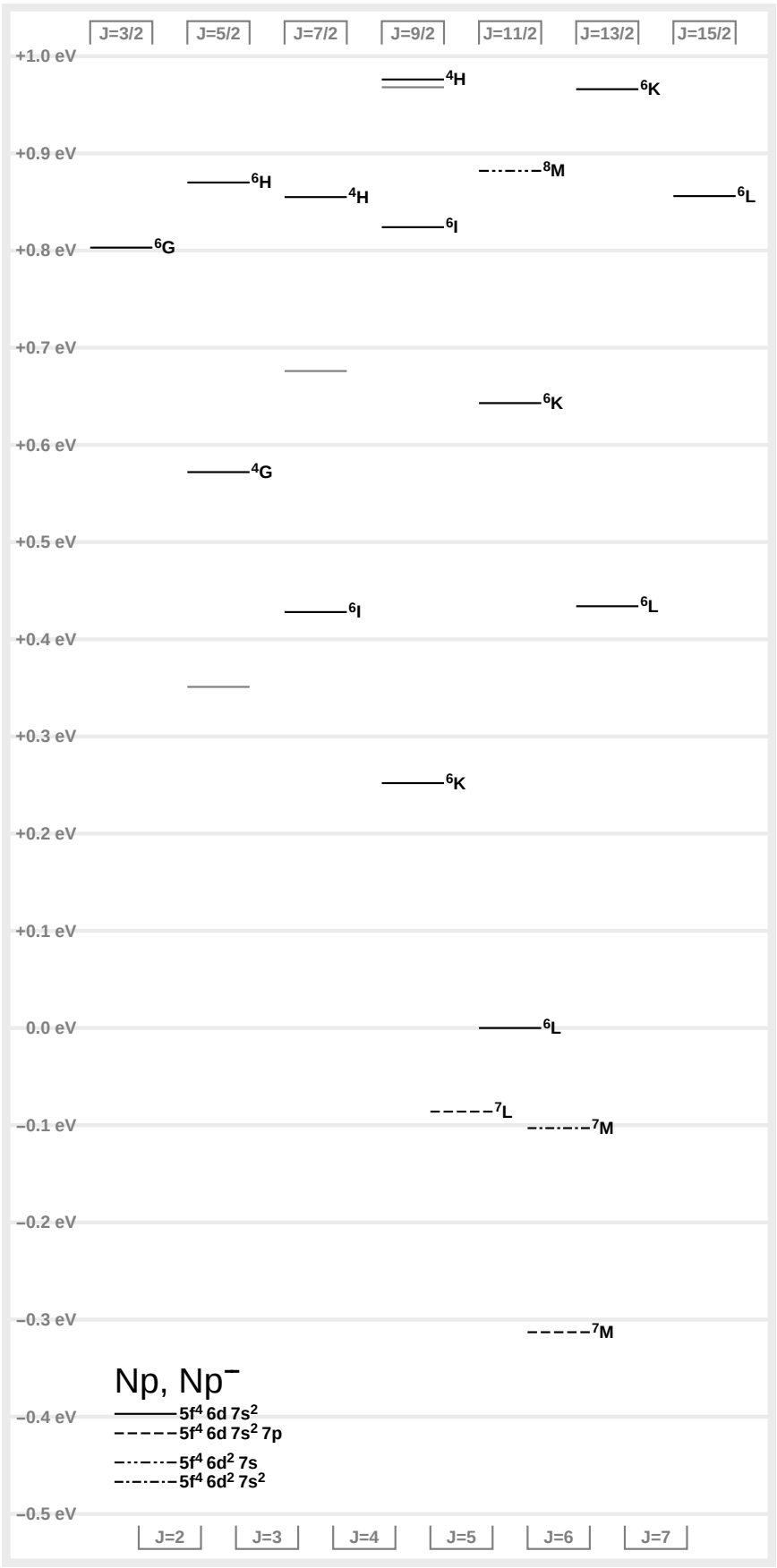
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−0.2 eV
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4H
6K
8M
6H
4H
6L
6I
6G
6K
4G
6I
6L
6K
6L
7L
7M
7M
Np, Np⁻
5f⁴ 6d 7s²
5f⁴ 6d 7s² 7p
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5f⁴ 6d² 7s²
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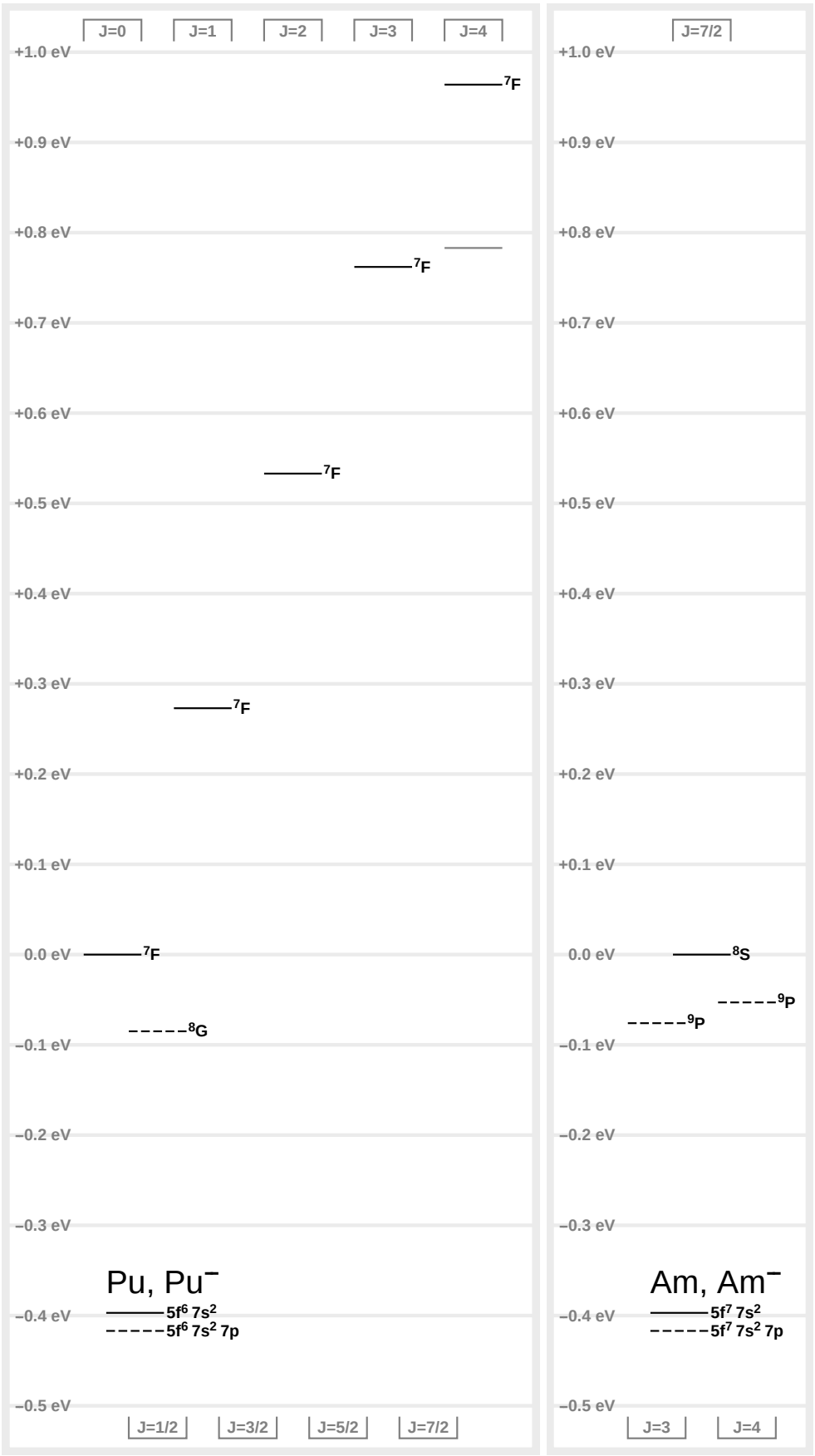
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+0.5 eV
+0.4 eV
+0.3 eV
+0.2 eV
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0.0 eV
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−0.3 eV
−0.4 eV
−0.5 eV
7F
7F
7F
7F
8G
8S
9P
9P
Pu, Pu⁻
5f6 7s2
5f6 7s2 7p
Am, Am⁻
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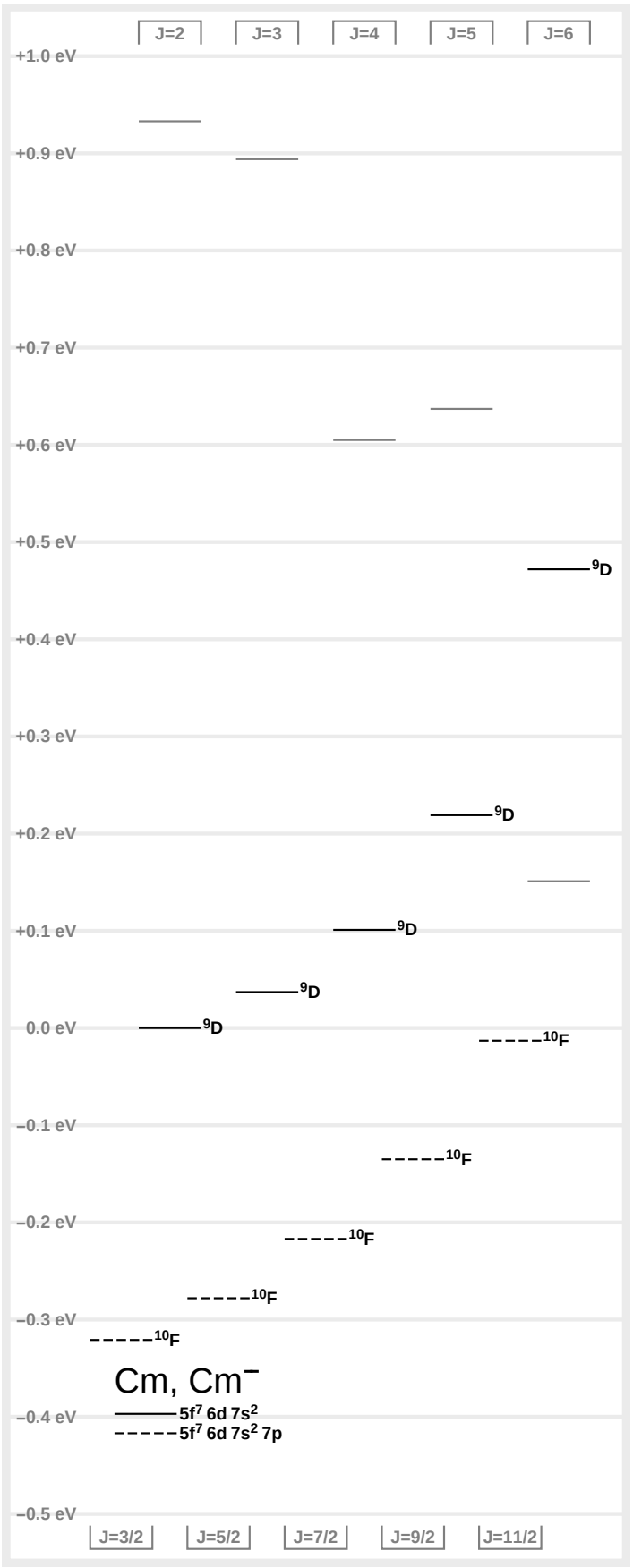
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9D
9D
9D
9D
9D
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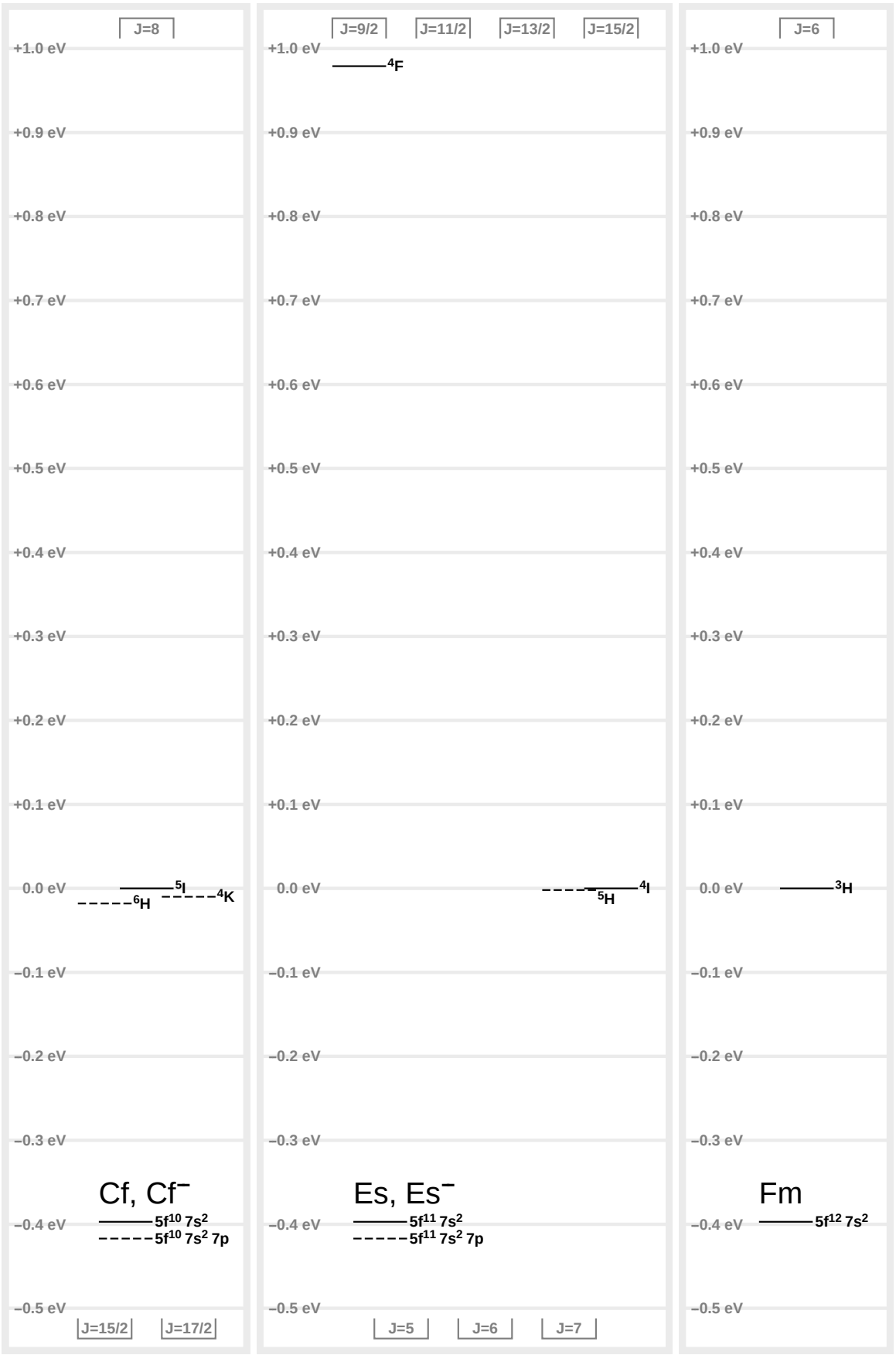
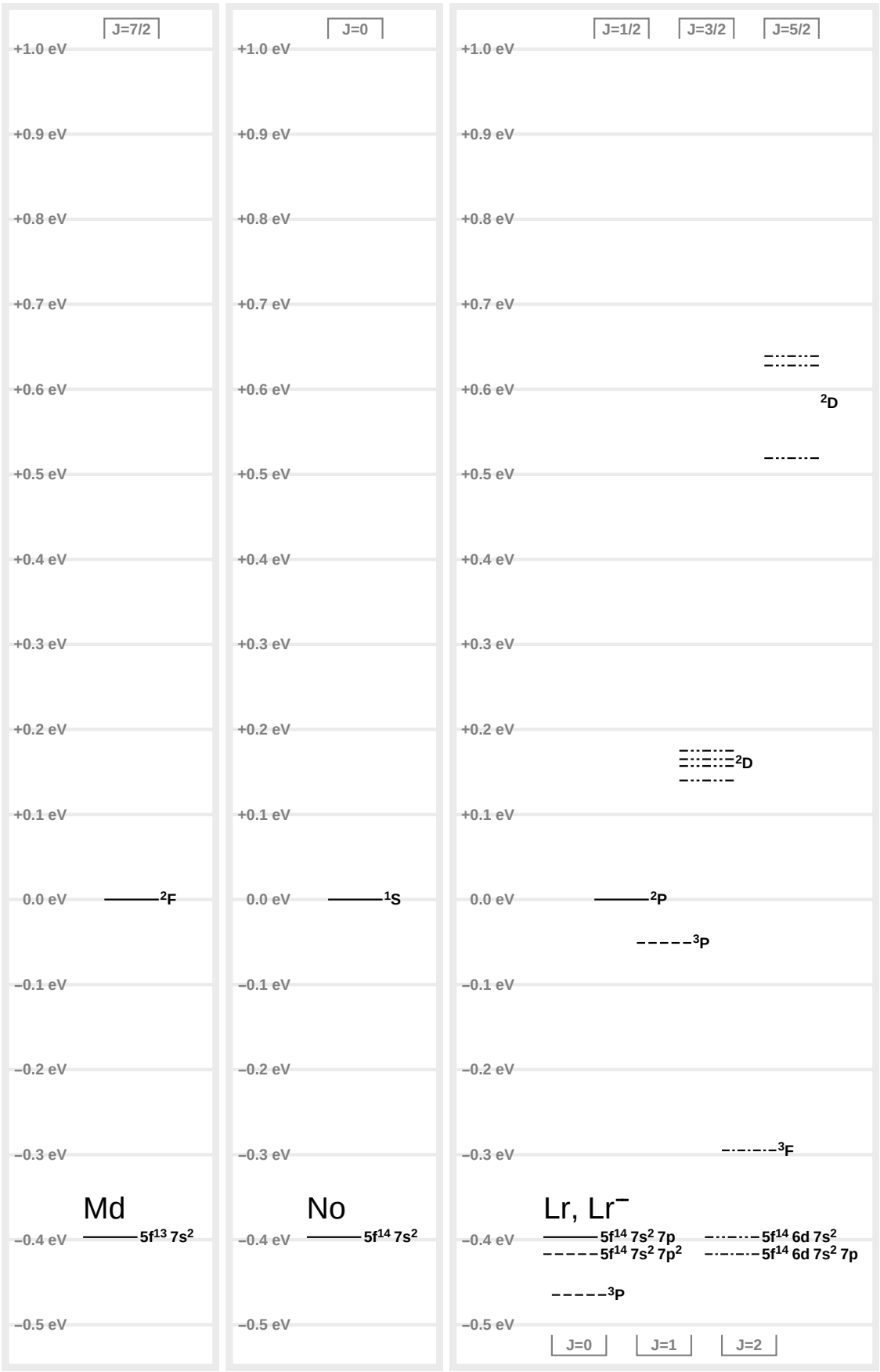
10F
10F
10F
10F
Cm, Cm⁻
5f7 6d 7s2
5f7 6d 7s2 7p
J=3/2
J=5/2
J=7/2
J=9/2
J=11/2


J=9/2
J=11/2
J=13/2
J=15/2
+1.0 eV
+0.9 eV
+0.8 eV
+0.7 eV
+0.6 eV
+0.5 eV
+0.4 eV
+0.3 eV
+0.2 eV
+0.1 eV
0.0 eV
−0.1 eV
−0.2 eV
−0.3 eV
−0.4 eV
−0.5 eV
6H
6F
6F
6H
7G
5I
Bk, Bk⁻
5f9 7s2
5f9 7s2 7p
J=5
J=6
J=7
J=8


J=8
+1.0 eV
+0.9 eV
+0.8 eV
+0.7 eV
+0.6 eV
+0.5 eV
+0.4 eV
+0.3 eV
+0.2 eV
+0.1 eV
0.0 eV
−0.1 eV
−0.2 eV
−0.3 eV
−0.4 eV
−0.5 eV
5I
6H
4K
Cf, Cf⁻
5f10 7s2
5f10 7s2 7p
J=15/2
J=17/2
J=9/2
J=11/2
J=13/2
J=15/2
4F
5H
4I
Es, Es⁻
5f11 7s2
5f11 7s2 7p
J=5
J=6
J=7
J=6
3H
Fm
5f12 7s2


J=7/2
J=0
J=1/2
J=3/2
J=5/2
+1.0 eV
+0.9 eV
+0.8 eV
+0.7 eV
+0.6 eV
+0.5 eV
+0.4 eV
+0.3 eV
+0.2 eV
+0.1 eV
0.0 eV
−0.1 eV
−0.2 eV
−0.3 eV
−0.4 eV
−0.5 eV
^{2}F
^{1}S
^{2}P
^{3}P
^{2}D
^{2}D
^{3}F
Md
5f^{13} 7s^2
No
5f^{14} 7s^2
Lr, Lr$^-$
5f^{14} 7s^2 7p
5f^{14} 7s^2 7p^2
^{3}P
5f^{14} 6d 7s^2
5f^{14} 6d 7s^2 7p
J=0
J=1
J=2