Exceptions to the Aufbau Principle

Unit: Electronic Structure

MA Curriculum Frameworks (2016): HS-PS1-1

Mastery Objective(s): (Students will be able to…)

- Predict which elements are likely to be exceptions to the aufbau principle.
- Explain why exceptions to the aufbau principle occur as you approach the middle and end of the d and f sub-levels.

Success Criteria:

- Predictions match observed electron configurations.

Language Objectives:

- Explain exceptions to the aufbau principle.

Notes:

Remember from Hund's Rule that electrons like to spread out.

Atoms are the most stable when their electrons are the most evenly distributed within the atom's energy levels and sub-levels. This means that elements with completely filled principal (numbered) energy levels are the most stable.

- The "noble gases" (the last column of the periodic table) already have all of their principal energy levels completely filled with electrons. This makes them very stable, because they do not need to react with other atoms to get their electrons into a more stable configuration. This is why noble gases almost never react with anything.
- Other elements gain, lose, or share electrons (in chemical reactions) in order to end up with electron configurations that are like the nearest noble gas on the periodic table.

Atoms with p, d, and f sub-levels that are exactly half full are more stable than atoms with slightly more or fewer electrons in their p, d, and f sub-levels. This makes those atoms slightly more stable (and therefore less reactive) than other atoms. For example:

- Nitrogen ([He] $2s^2$ $2p^3$), which has an exactly half-filled 2p sub-level, is chemically less reactive than oxygen ([He] $2s^2$ $2p^4$).
- Manganese ([Ar] $4s^2$ $3d^5$), which has an exactly half-full 3d sub-level, is chemically less reactive than iron ([Ar] $4s^2$ $3d^6$).

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In fact, elements with a d or f sub-level that is one electron away from being half full will usually “borrow” one electron from the nearest s sub-level, because the half-filled d or f sub-level is more stable than the full s sub-level.

- Chromium “borrows” one of its 4s electrons to make its 3d sub-level exactly half full. This means that instead of having predicted electron configuration of [Ar] $4s^2$ $3d^4$, it is observed to have the electron configuration [Ar] $4s^1$ $3d^5$. This happens because a half-filled 4s sub-level plus a half-filled 3d sub-level is more stable than a completely filled 4s sub-level plus a 3d sub-level with 4 electrons in it.
- Copper “borrows” one of its 4s electrons to make its 3d sub-level completely full. This means that instead of having predicted electron configuration of [Ar] $4s^2$ $3d^9$, it is observed to have the electron configuration [Ar] $4s^1$ $3d^{10}$. Again, this happens because a half-filled 4s sub-level plus a completely filled 3d sub-level is more stable than a completely filled 4s sub-level plus a 3d sub-level with 9 electrons in it.

There are a significant number of other exceptions to the aufbau principle. Clearly, atoms do not care about the periodic table!

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