Name ____ Pd ____ Date _____________________________

Transition Elements & Electron Configuration: Understanding the Exceptions

The Aufbau Principle, Pauli Exclusion Principle and Hund's Rule give us a set of rules to determine the order in which electrons occupy the energy sub-levels and orbitals within each sub-level. These rules are consistent and clear cut when it comes to determining the electron configurations for the *representative elements* (all the elements in groups 1, 2 and 13 through 18). These rules still hold true for the *transition elements* and *inner transition elements*, but applying them is not as clear cut as it is with the representative elements. The exceptions for the inner transition elements are very complex to understand and beyond the scope of an introductory college chemistry course. However, we can figure out the exceptions for the transition elements with two additional pieces of information.

1. The *n*s and *(n-1)*d sub-levels are very close to each other in energy. In other words, there is not much difference in energy between the 4s sub-level and the 3d sub-level. The same holds true for the 5s and 4d sub-levels, the 6s and 5d sub-levels, and the 7s and 6d sub-levels.
2. Half-filled and completely filled sub-levels are more stable than sub-levels that are not half-filled or completely filled.

This extra stability for half-filled sub-levels coupled with small energy difference between the *n*s and *(n-1)*d sub-levels results in electrons sometimes occupying the *(n-1)*d sub-level before the *n*s sub-level is completely filled. Specifically, this occurs in transition metals when leaving the *n*s sub-level half-filled results in a half-filled or completely filled *(n-1)*d sublevel.

Let's look at the two exceptions that occur in the fourth period (aka row) of the periodic table. We would expect chromium (Cr) to have an electron configuration of $[Ar]4s^2 3d^4$, but its actual electron configuration is $[Ar]4s^1 3d^5$.

The expected electron configuration for chromium would leave the 3d sub-level less than half-filled.

↑↓	↑	↑	↑	↑	
4s			3d		

The actual electron configuration for chromium results in half-filled 4s and 3d sub-levels, which is more stable than the expected configuration.

↑	↑	↑	↑	↑	↑
4s			3d		

The other exception in the fourth period occurs with copper (Cu). We would expect copper (Cu) to have an electron configuration of $[Ar]4s^2 3d^9$, but its actual electron configuration is $[Ar]4s^1 3d^{10}$.

The expected electron configuration for copper would leave the 3d sub-level more than half-filled, but not completely filled.

↑↓	↑↓	↑↓	↑↓	↑↓	↑
4s			3d		

The actual electron configuration for chromium results in a half-filled 4s sub-level and a completely filled 3d sub-level, which is more stable than the expected configuration.

↑	↑↓	↑↓	↑↓	↑↓	↑↓
4s			3d		

1. Write the noble gas notation for the transition elements below.

Element	Noble Gas Notation	Element	Noble Gas Notation
titanium		vanadium	
chromium		manganese	
iron		cobalt	
nickel		Krypton	
zirconium		molybdenum	
technetium		ruthenium	$[Kr]5s^1 4d^7$ an exception to the exception
rhodium	$[Kr]5s^1 4d^8$ an exception to the exception	palladium	$[Kr]4d^{10}$ an exception to the exception
silver		tungsten	
rhenium		osmium	
iridium		platinum	$[Xe]6s^1 5d^9$ an exception to the exception
gold		rutherfordium	
dubnium		seaborgium	

2. Compare and contrast the electron configurations for the transition elements listed above and the transition metals you completed in the previous worksheet. How does their electron configuration relate to their period (aka row) and group (aka column) in the periodic table?