CHEM 103
R&R 12
17 June 2024
Adapted from a 22 June 2021 document

1. In the ground state of cadmium (Cd):

a. Write the full and noble gas notation ground state electron configuration.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2$ [Kr] $4d^{10} 5s^2$

b. How many electrons have l = 2 as one of their quantum numbers?

$l = 2 \rightarrow$ d orbital. **20 e^-**

c. How many electrons have n = 4 as one of their quantum numbers?

18 e^-

d. How many electrons have m_l = -1 as one of their quantum numbers?

$\frac{1}{3}$ of $l = 1$ (p orbital) + $\frac{1}{5}$ of $l = 2$ (d orbital) $\rightarrow$ **10 e^-**

2. Write the full and noble gas notation ground state electron configuration for the following elements:

a. Tellurium

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^4$; [Kr] $4d^{10} 5s^2 5p^4$

b. Cesium

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 6s^1$; [Xe] $6s^1$

c. Arsenic

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$; [Ar] $3d^{10} 4s^2 4p^3$

d. Iridium

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^7 6s^2$; [Xe] $4f^{14} 5d^7 6s^2$

e. Copper

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$; [Ar] $3d^{10} 4s^1$ ← more stable than [Ar] $3d^9 4s^2$

3. The successive ionization energies for an unknown elements are I_1 = 896 kJ mol^{-1}; I_2 = 1752 kJ mol^{-1}; I_3 = 14807 kJ mol^{-1}; I_4 = 17948 kJ mol^{-1}. To which group in the periodic table does the unknown element most likely belong?

Large jump from I_2 to I_3 ⇒ Element has two valence electrons. The element is in group 2.

4. Two elements, A and B, have the electron configuration shown:

A – [Ar] $4s^2$ and B – [Ar] $3d^{10}$ $4s^2$ $4p^5$

a. Which element is a metal?

A (group 2)

b. Which element has the greater ionization energy?

B (greater effective nuclear charge)

c. Which element has the larger atomic radius?

A (lower Z_{eff})

d. Which element has the greater electron affinity?

B (one e^- away from stable configuration)

5. Write the noble gas notation ground state electron configuration of mercury:

[Xe] $4f^{14}$ $5d^{10}$ $6s^2$

a. How many electrons occupy atomic orbitals with n = 3?

18 (3s, 3p, 3d all full)

b. How many electrons occupy d atomic orbitals?

30 (3d, 4d, 5d all full)

c. How many electrons have spin "up" (m = +½)?

40 (all suborbitals full ⇒ half are spin up)

6. Write a complete set of quantum numbers for each of the electrons in the Cu valence shell:

$n = 4,\ l = 0,\ m_l = 0,\ m_s = +\frac{1}{2}$

a. Write the complete electron configuration for the Cu^{2+} ion:

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$

b. If the first and second ionizations of copper are 745.4 kJ mol^{-1} and 1957.9 kJ mol^{-1} respectively, what are the wavelengths of the photons emitted upon ionization?

$$\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\ \text{J}\cdot\text{s})(3.00\times10^{8}\ \frac{\text{m}}{\text{s}})}{(745.4\times10^{3}\ \text{J})(6.022\times10^{23})^{-1}} = 1.61\times10^{-7}\ \text{m} = 161\ \text{nm}$$

$$\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\ \text{J}\cdot\text{s})(3.00\times10^{8}\ \frac{\text{m}}{\text{s}})}{(1957.9\times10^{3}\ \text{J})(6.022\times10^{23})^{-1}} = 6.11\times10^{-8}\ \text{m} = 61.1\ \text{nm}$$

7. Within any period, noble gases have the highest ionization energy. Why?

There are multiple ways to explain this fact. For one, we can consider the valence electron configuration. With each valence orbital filled by two electrons, the octet is considerably more stable than with one fewer electron.

We can also consider the effective nuclear charge, Z_{eff}. Within a period, noble gases have the greatest Z_{eff} = [# protons] − [# non-valence electrons], leading to a greater pull on the valence electrons.

Fun fact: noble gases are called "noble" for the same reason that "noble metals" (Ru, Rh, Pd, Os, Ir, Pt, and Au) are—not because they are expensive (though they can be!), but rather because they can be resistant to reacting. The idea is that these "noble" elements are too stuck-up to mingle with the commoner elements. (This may be apocryphal, but I think it's fun.)