Electronic Configurations of Ions
Representative Elements

P When atoms form ions, electrons are gained or lost in the valence shell.

P To form an anion, electrons are added to the lowest energy available orbitals.

\[
\begin{align*}
\text{F} & \quad 1s^22s^22p^5 & \quad \text{F}^- & \quad 1s^22s^22p^6 = [\text{Ne}] \\
\text{O} & \quad 1s^22s^22p^4 & \quad \text{O}^{2-} & \quad 1s^22s^22p^6 = [\text{Ne}] \\
\text{N} & \quad 1s^22s^22p^3 & \quad \text{N}^{3-} & \quad 1s^22s^22p^6 = [\text{Ne}]
\end{align*}
\]

P To form a cation of a non-transition element, electrons are lost from the highest-energy occupied orbitals.

\[
\begin{align*}
\text{Na} & \quad [\text{Ne}]3s^1 & \quad \text{Na}^+ & \quad [\text{Ne}]3s^0 = [\text{Ne}] \\
\text{Mg} & \quad [\text{Ne}]3s^2 & \quad \text{Mg}^{2+} & \quad [\text{Ne}]3s^0 = [\text{Ne}] \\
\text{Al} & \quad [\text{Ne}]3s^23p^1 & \quad \text{Al}^{3+} & \quad [\text{Ne}]3s^0 = [\text{Ne}] \\
\text{Ga} & \quad [\text{Ar}]3d^{10}4s^24p^1 & \quad \text{Ga}^{3+} & \quad [\text{Ar}]3d^{10}
\end{align*}
\]

U Cations of elements in groups 13, 14, and 15 in the fourth or higher periods do not have noble gas configurations, because they have completely filled \(nd\) subshells.
Electronic Configurations of Ions
Heavy Elements in Groups 13, 14, 15

Heavier elements in these groups sometimes form cations with charges two less than the group-characteristic charge. In these cases the $ns^2$ electrons of the valence configuration are retained:

\[ {}_{81}^{\text{Tl}} \; [\text{Xe}]^4f^{14}5d^{10}6s^26p^1 \quad \text{Tl}^{+} \; [\text{Xe}]^4f^{14}5d^{10}6s^2 = [\text{Hg}] \]
\[ \text{Tl}^{3+} \; [\text{Xe}]^4f^{14}5d^{10} = [\text{Hg}^{2+}] \]
Electronic Configurations of Transition Metal Cations

When forming cations of transition elements, the outermost ns electrons are lost before any electrons in the (n - 1)d subshell.

$^{26}\text{Fe}$ \([\text{Ar}]3d^64s^2\)  \quad \text{Fe}^{2+} \quad [\text{Ar}]3d^6$

$^{26}\text{Fe}$ \[\text{Ar}]3d^6$  \quad \text{Fe}^{2+} \quad [\text{Ar}]3d^6$

$^{29}\text{Cu}$ \([\text{Ar}]3d^{10}4s^1\)  \quad \text{Cu}^+ \quad [\text{Ar}]3d^{10}$

$^{29}\text{Cu}$ \[\text{Ar}]3d^{10}$  \quad \text{Cu}^{2+} \quad [\text{Ar}]3d^9$
Magnetic Properties and Electronic Structure

U The magnetic properties of a substance can be measured with apparatus such as the **Gouy balance**.

P Paired electrons in a substance cause a weak repulsion for the magnetic field, due to an induced magnetic moment, making the sample appear to be lighter.

P Unpaired electrons have a permanent magnetic moment, which is attracted to the magnetic field, making the sample appear to be heavier.
Diamagnetic or Paramagnetic

\begin{align*}
\text{Ne} & \quad 1s^22s^22p^6 \quad \text{all paired} \quad \text{diamagnetic} \\
\text{Na} & \quad 1s^22s^22p^63s^1 \quad \text{one unpaired electron} \quad \text{paramagnetic} \\
\text{F} & \quad 1s^22s^22p^5 \quad \text{one unpaired electron} \quad \text{paramagnetic} \\
\text{Cu} & \quad [Ar]3d^{10}4s^1 \quad \text{one unpaired electron} \quad \text{paramagnetic} \\
\text{Zn} & \quad [Ar]3d^{10}4s^2 \quad \text{all paired} \quad \text{diamagnetic}
\end{align*}

Atoms with even numbers of electrons are not necessarily diamagnetic:

\begin{align*}
\text{O} & \quad 1s^22s^22p^4 \quad \text{2 unpaired} \quad \text{paramagnetic} \\
\text{Fe} & \quad [Ar]3d^64s^2 \quad \text{4 unpaired} \quad \text{paramagnetic}
\end{align*}
Diamagnetism and Paramagnetism of Ions

All ions that have an electronic structure isoelectronic with one of the noble gases or have any other closed-subshell configuration are diamagnetic.

\[ \text{O}^{2-} = [\text{Ne}] \quad \text{Cl}^- = [\text{Ar}] \]
\[ \text{Na}^+ = [\text{Ne}] \quad \text{Mg}^{2+} = [\text{Ne}] \]
\[ \text{Ga}^{3+} = [\text{Ar}]3d^{10} \quad \text{Tl}^+ = [\text{Xe}]4f^{14}5d^{10}6s^2 \]

Transition element ions are most often paramagnetic, because they have incompletely filled \(d\) subshells.

\[ \text{Fe}^{2+} \quad [\text{Ar}]3d^6 \quad \text{Ü} \quad \text{Ü} \quad \text{Ü} \quad \text{Ü} \quad \text{Ü} \]
4 unpaired \(\uparrow\) \(\uparrow\) paramagnetic

\[ \text{Fe}^{3+} \quad [\text{Ar}]3d^5 \quad \text{Ü} \quad \text{Ü} \quad \text{Ü} \quad \text{Ü} \quad \text{Ü} \]
5 unpaired \(\uparrow\) \(\uparrow\) \(\uparrow\) \(\uparrow\) \(\uparrow\) paramagnetic