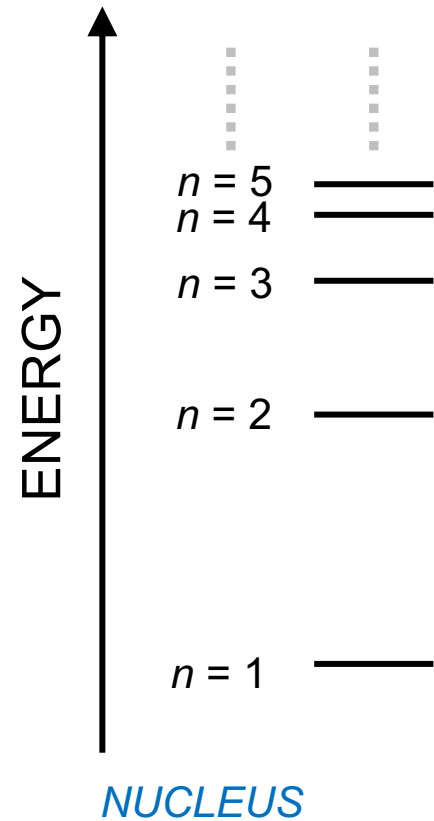
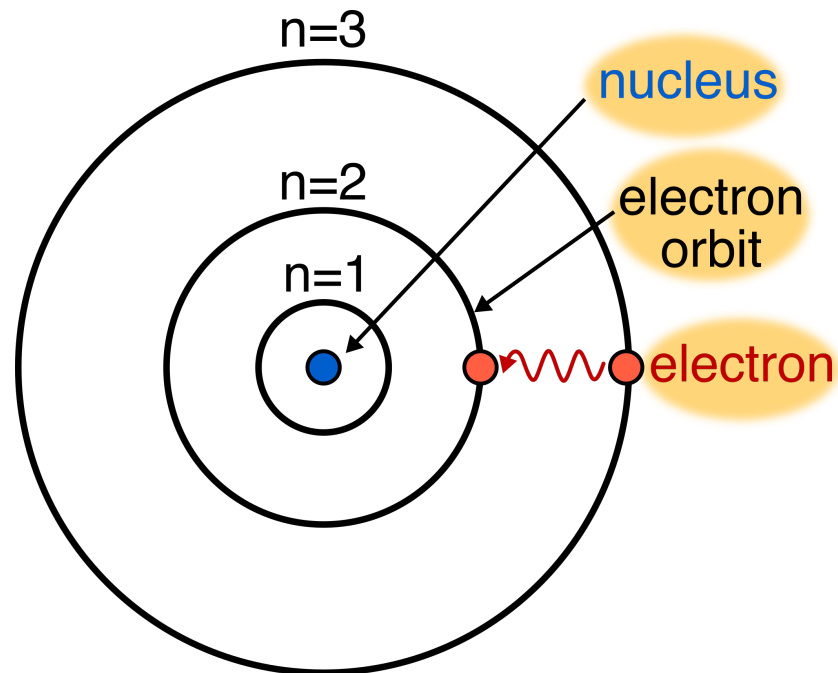


# Periodic Trends

**DR. MIOY T. HUYNH**  
YALE UNIVERSITY  
CHEMISTRY 161  
FALL 2019

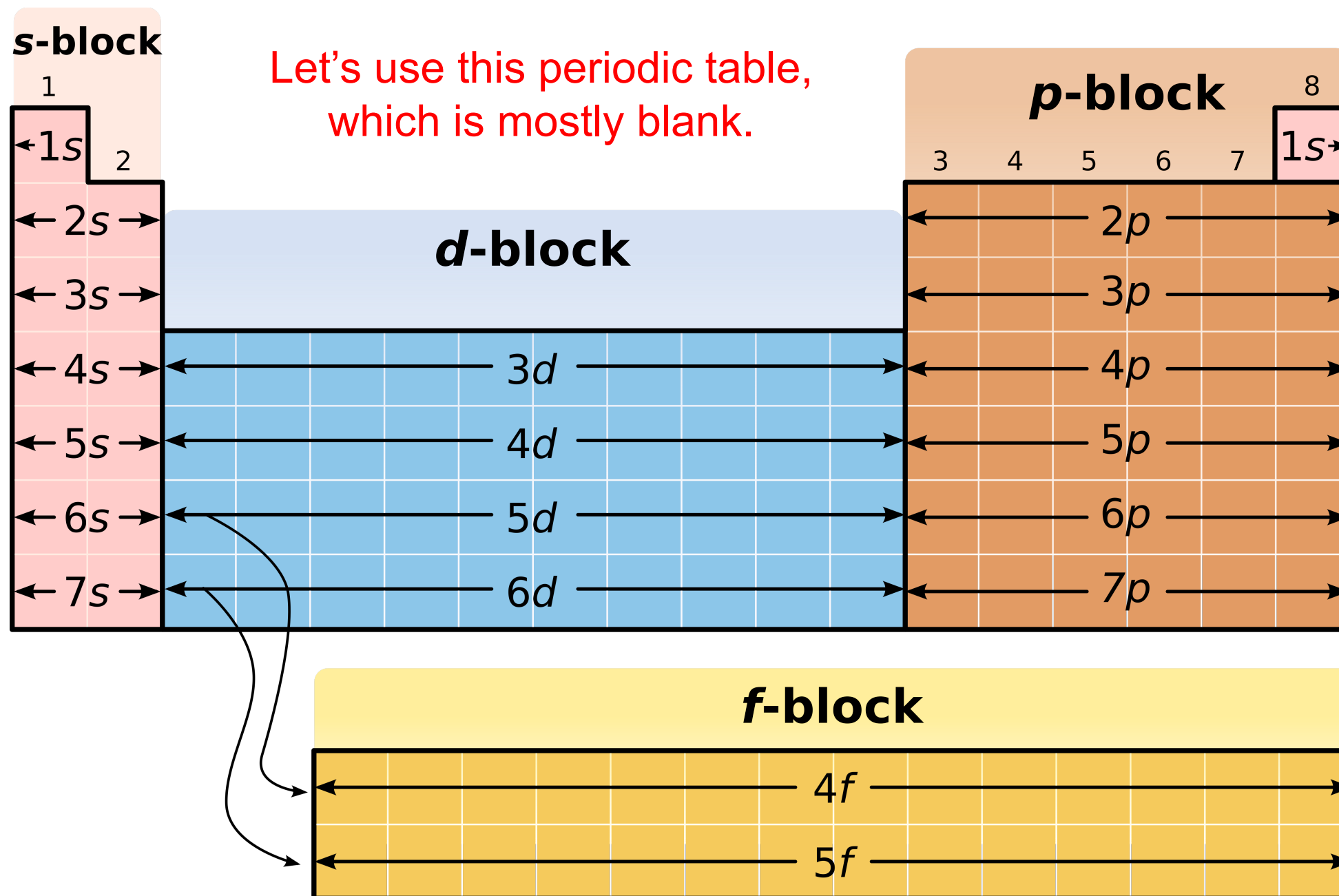
[www.mioy.org/chem161](http://www.mioy.org/chem161)

# Recall the Bohr Model

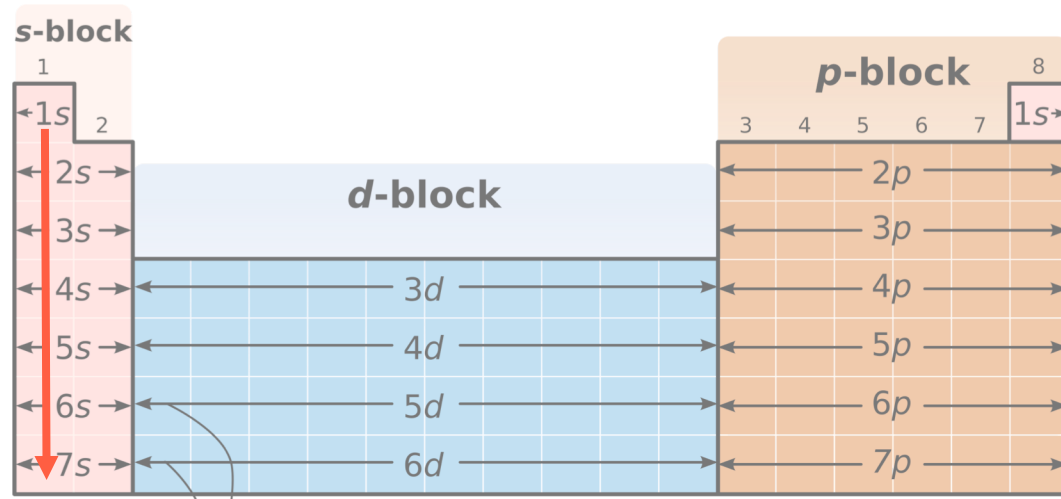


If we imagine the nucleus at the center, then:

- $n = 1$  has the lowest energy.
- $n = 2$  has the second lowest energy.
- The energies get higher the farther we get from the nucleus.
- The spacing between states also gets smaller!

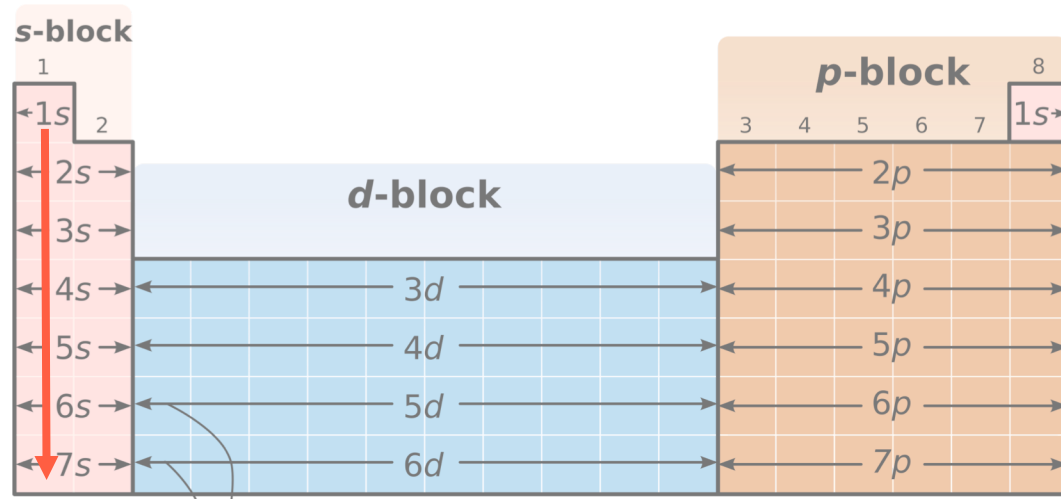


# ATOMIC RADIUS



Size increases down a column:

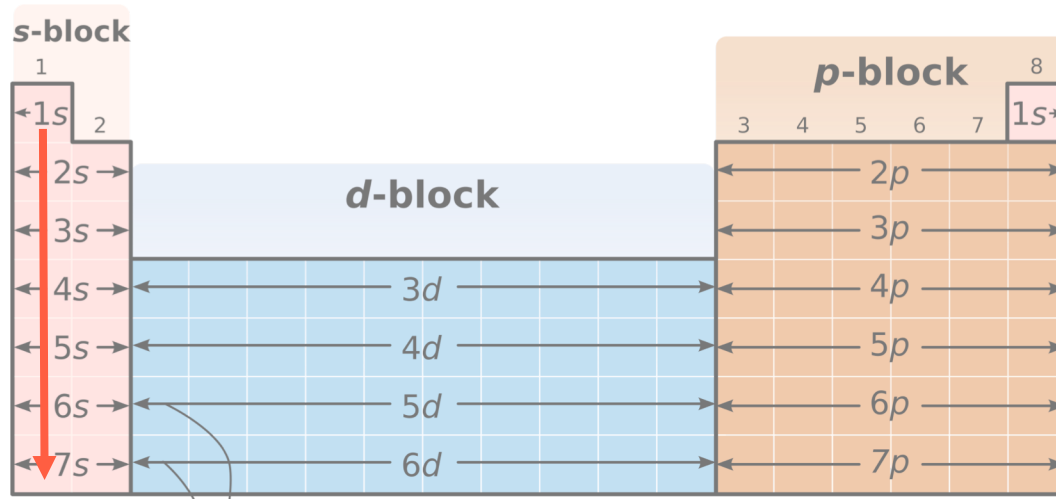
# ATOMIC RADIUS



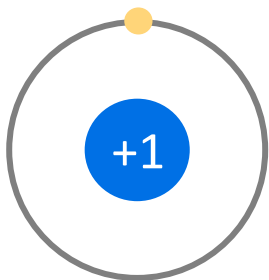
Size increases down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.

# ATOMIC RADIUS



H

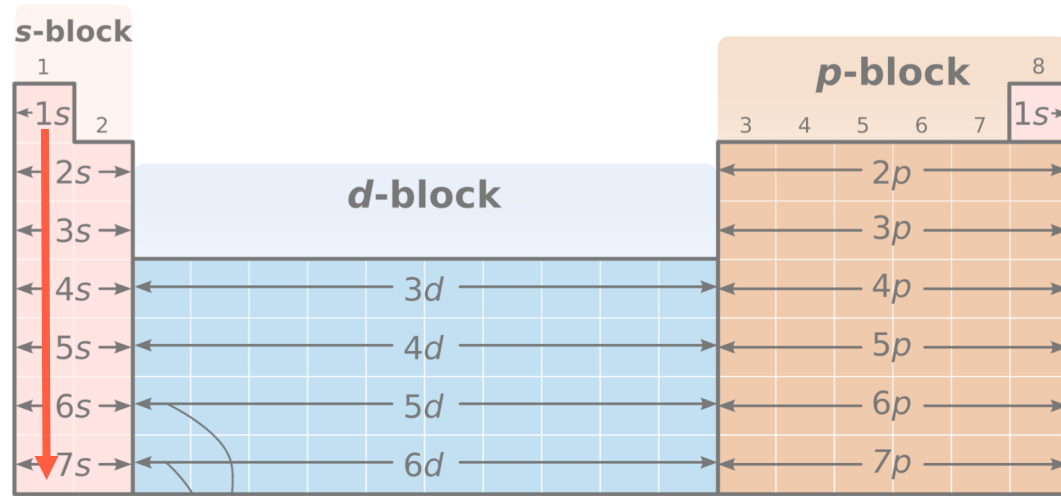


$1s^1$

Size increases down a column:

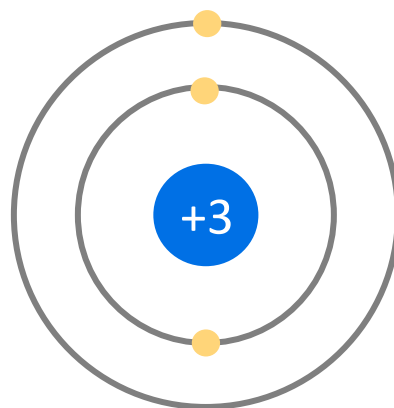
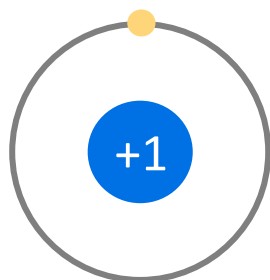
- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.

# ATOMIC RADIUS



H

Li



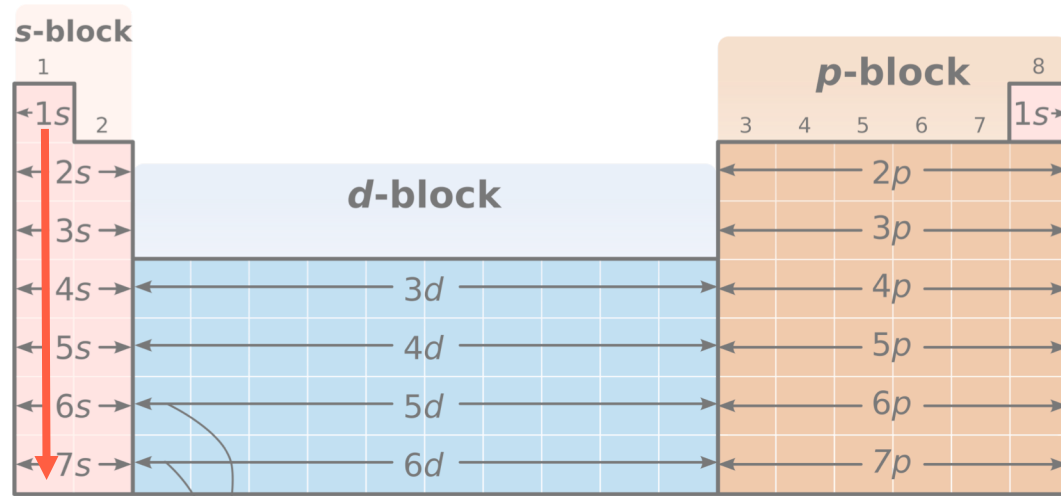
$1s^1$

$[\text{He}]2s^1$

Size increases down a column:

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- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.

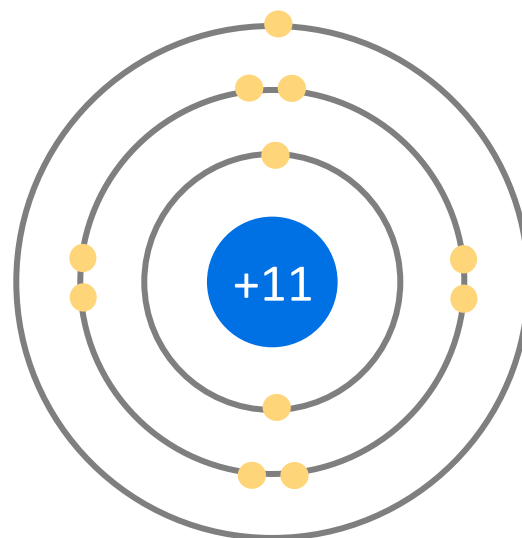
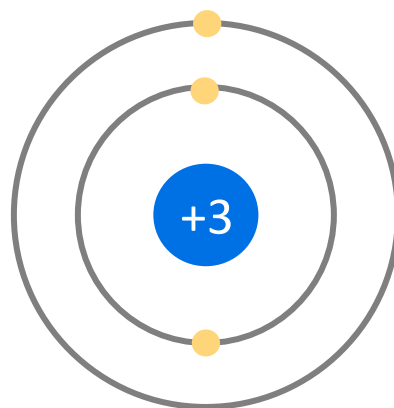
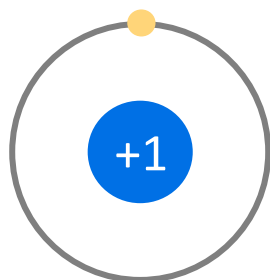
# ATOMIC RADIUS



H

Li

Na



$1s^1$

$[\text{He}]2s^1$

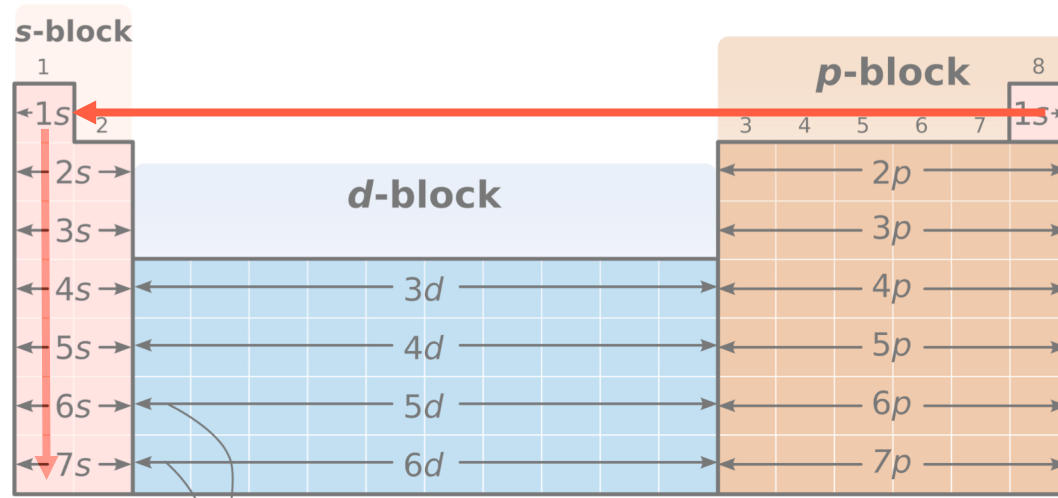
$[\text{Ne}]3s^1$

Size increases down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.



# ATOMIC RADIUS

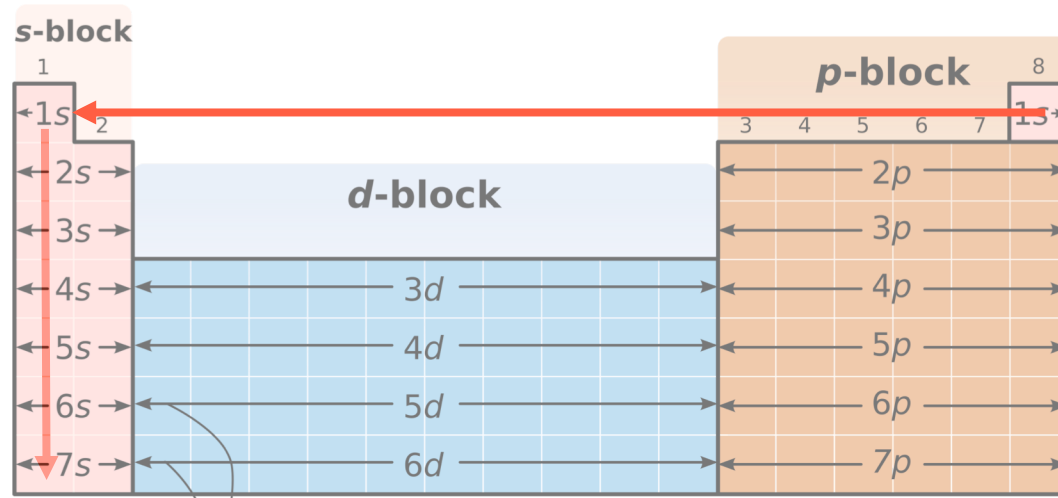


Size increases down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.

Size decreases across a row:

# ATOMIC RADIUS



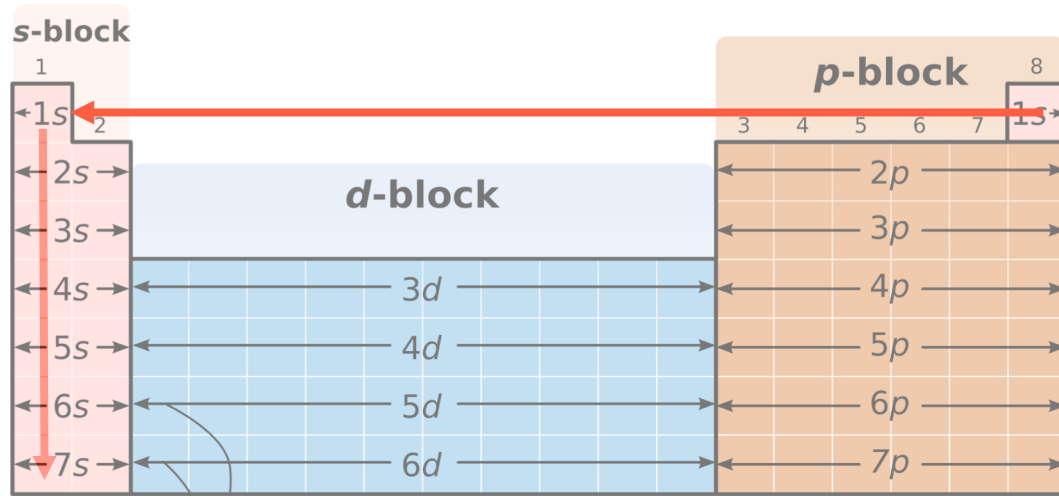
## Size increases down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.

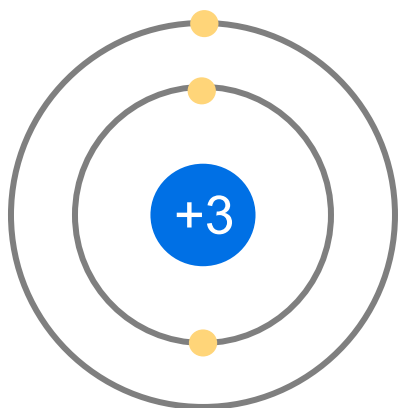
## Size decreases across a row:

- Adding **electrons** to the same energy level ( $n$ ).
- But also have more and more **protons** (positive charge).
- **Electrons** are pulled more tightly by increased number of **protons** (i.e. greater positive charge of nucleus).

# ATOMIC RADIUS



Li



[He]2s<sup>1</sup>

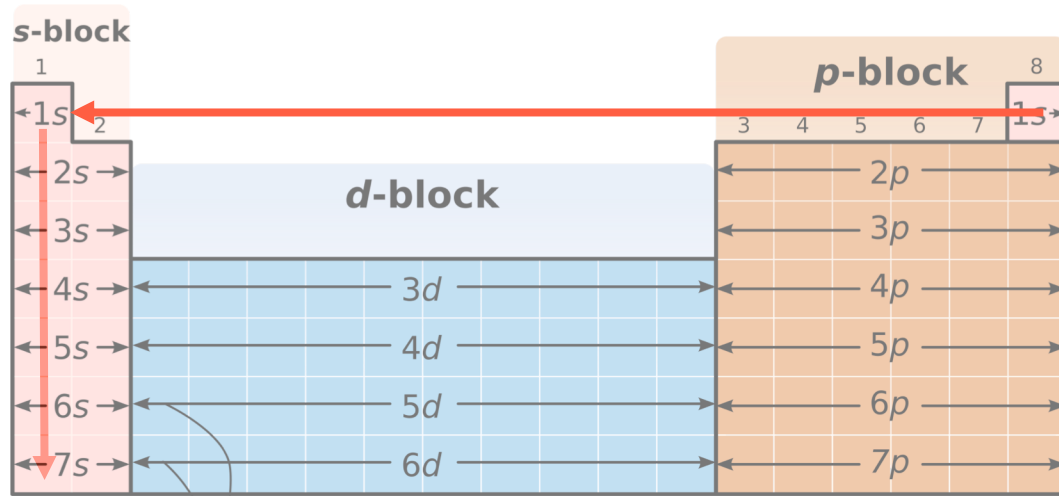
Size increases down a column:

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- Less pull from the positively charged **nucleus**.

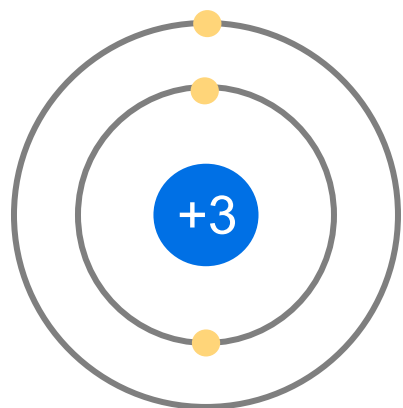
Size decreases across a row:

- Adding **electrons** to the same energy level ( $n$ ).
- But also have more and more **protons** (positive charge).
- **Electrons** are pulled more tightly by increased number of **protons** (i.e. greater positive charge of nucleus).

# ATOMIC RADIUS

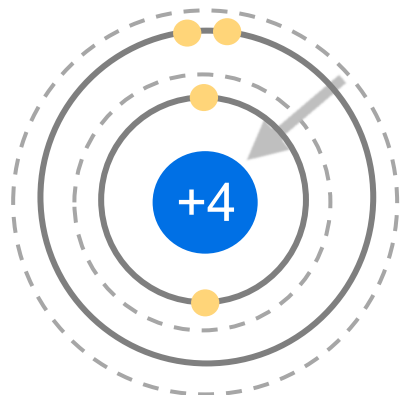


Li



[He]2s<sup>1</sup>

Be



[He]2s<sup>2</sup>

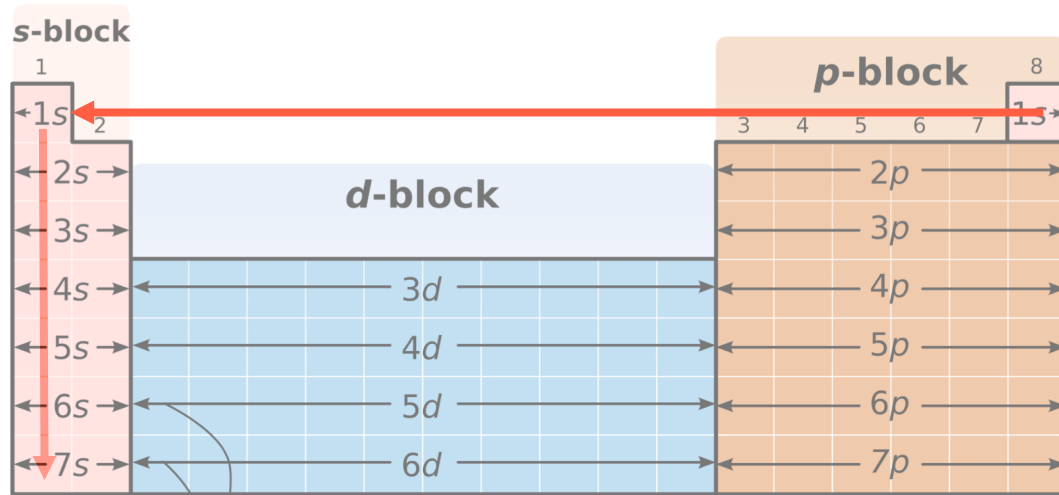
Size increases down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.

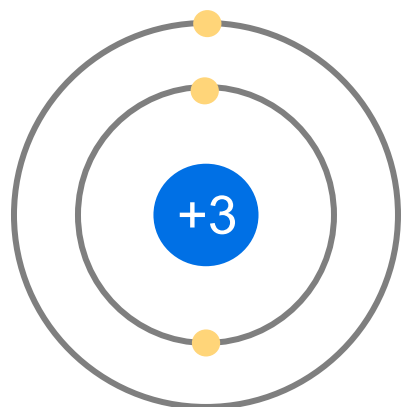
Size decreases across a row:

- Adding **electrons** to the same energy level ( $n$ ).
- But also have more and more **protons** (positive charge).
- **Electrons** are pulled more tightly by increased number of **protons** (i.e. greater positive charge of nucleus).  
→ Gray arrows show contraction of orbitals and overall atomic size.

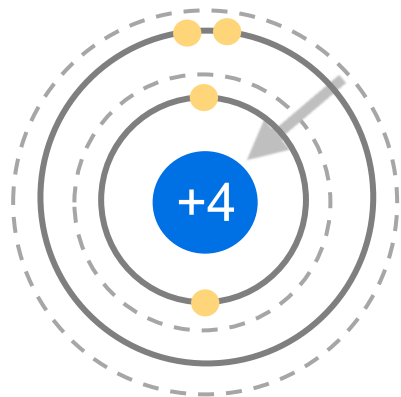
# ATOMIC RADIUS



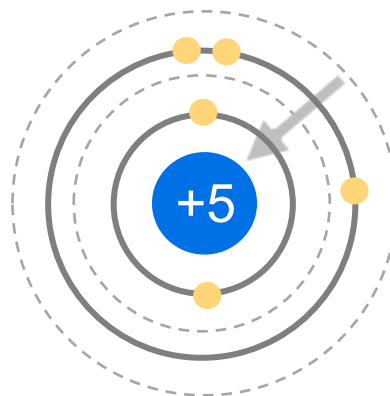
Li

[He]2s<sup>1</sup>

Be

[He]2s<sup>2</sup>

B

[He]2s<sup>2</sup>2p<sup>1</sup>

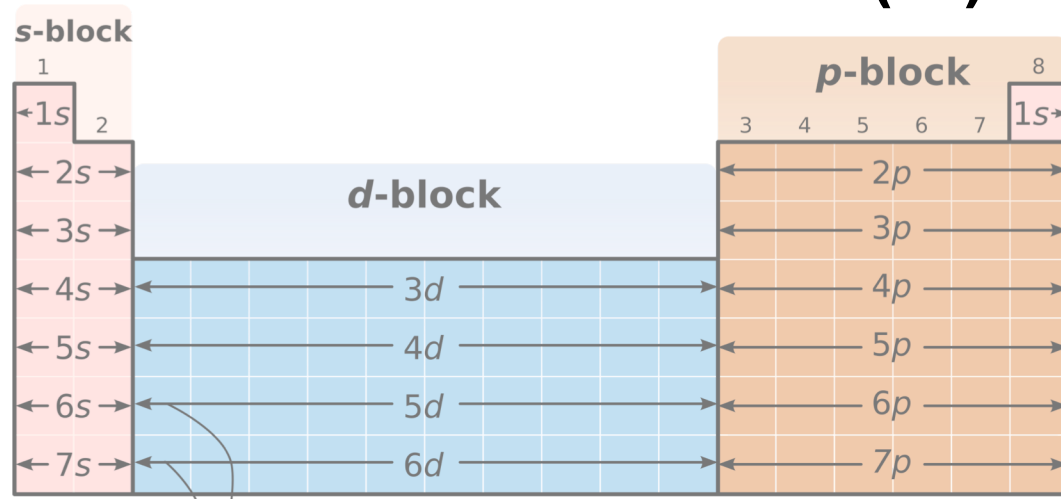
Size increases down a column:

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- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus**.

Size decreases across a row:

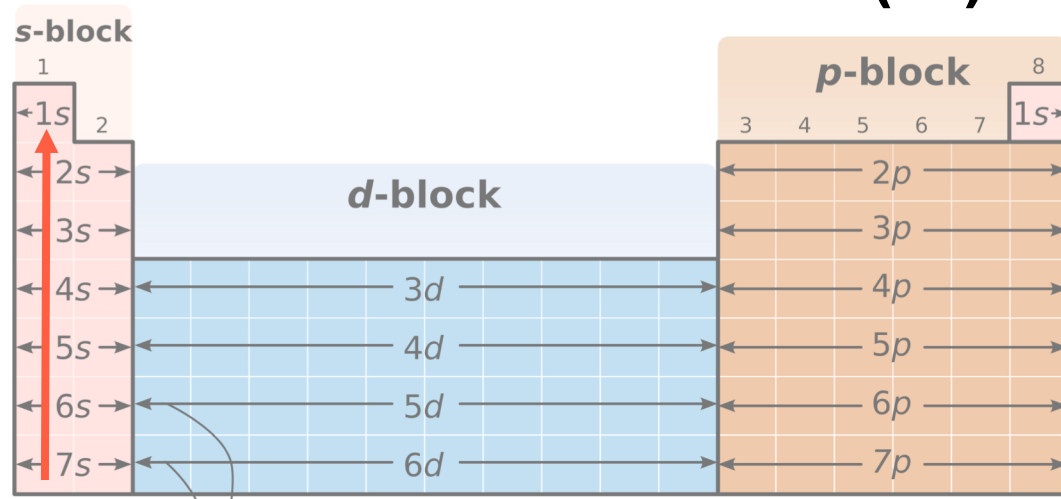
- Adding **electrons** to the same energy level ( $n$ ).
- But also have more and more **protons** (positive charge).
- **Electrons** are pulled more tightly by increased number of **protons** (i.e. greater positive charge of nucleus).  
→ Gray arrows show contraction of orbitals and overall atomic size.

# IONIZATION ENERGY (IE)



Energy to remove outermost electron.

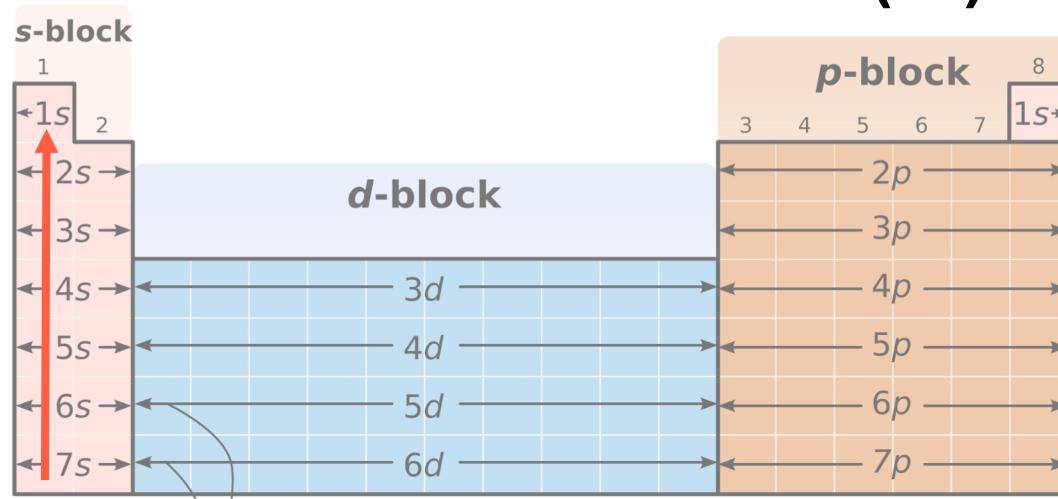
# IONIZATION ENERGY (IE)



Energy to remove outermost electron.

IE decreases down a column:

# IONIZATION ENERGY (IE)



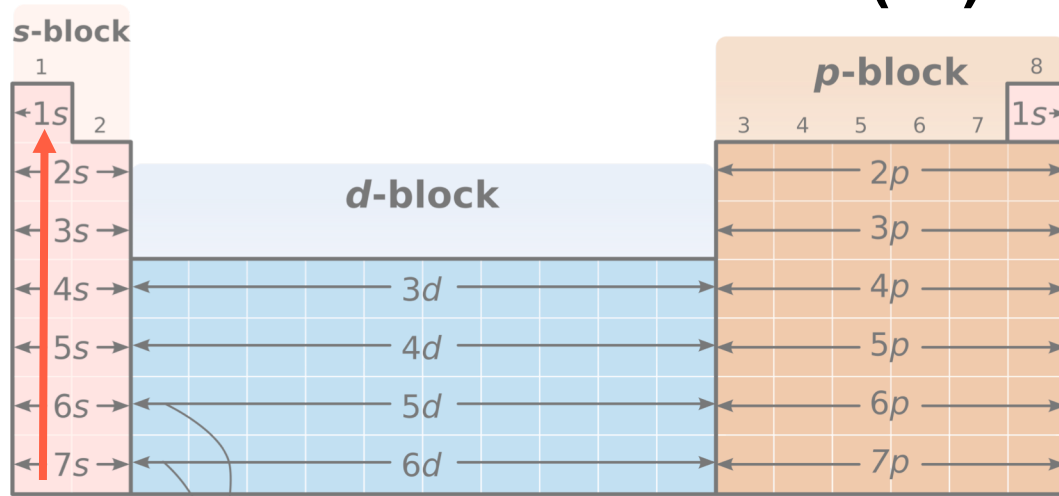
Energy to remove outermost electron.

**IE decreases down a column:**

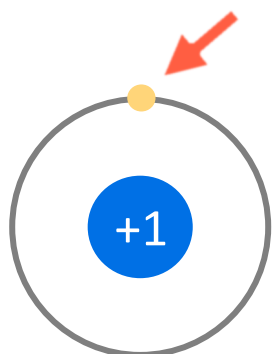
- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus** → easier to remove!



# IONIZATION ENERGY (IE)



H



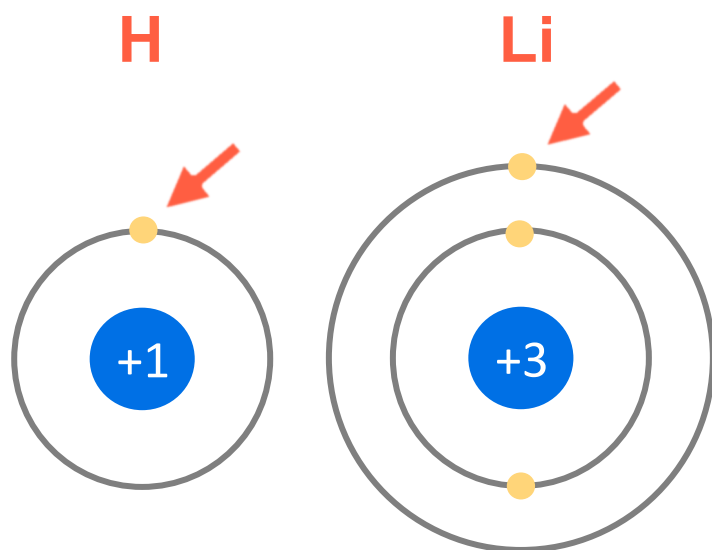
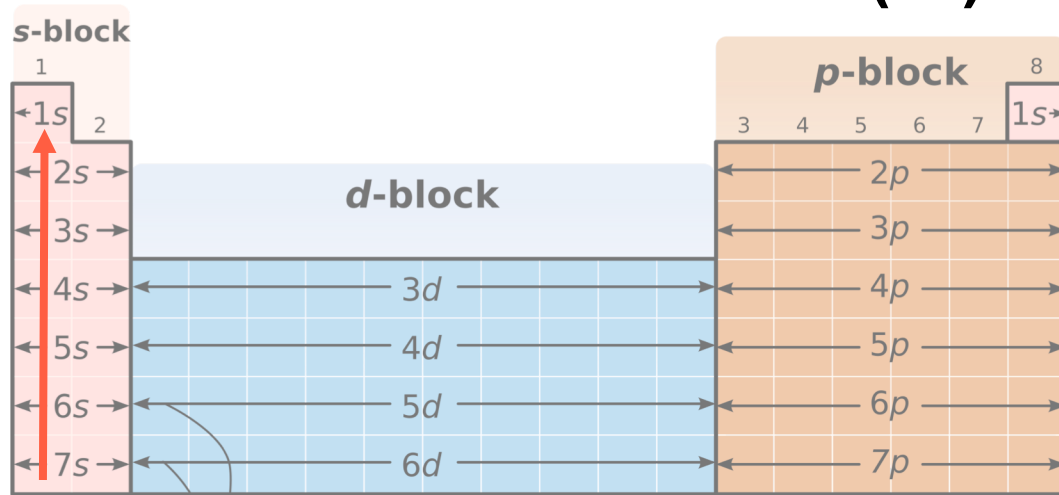
$1s^1$

Energy to remove outermost electron.

**IE decreases down a column:**

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus** → easier to remove!

# IONIZATION ENERGY (IE)

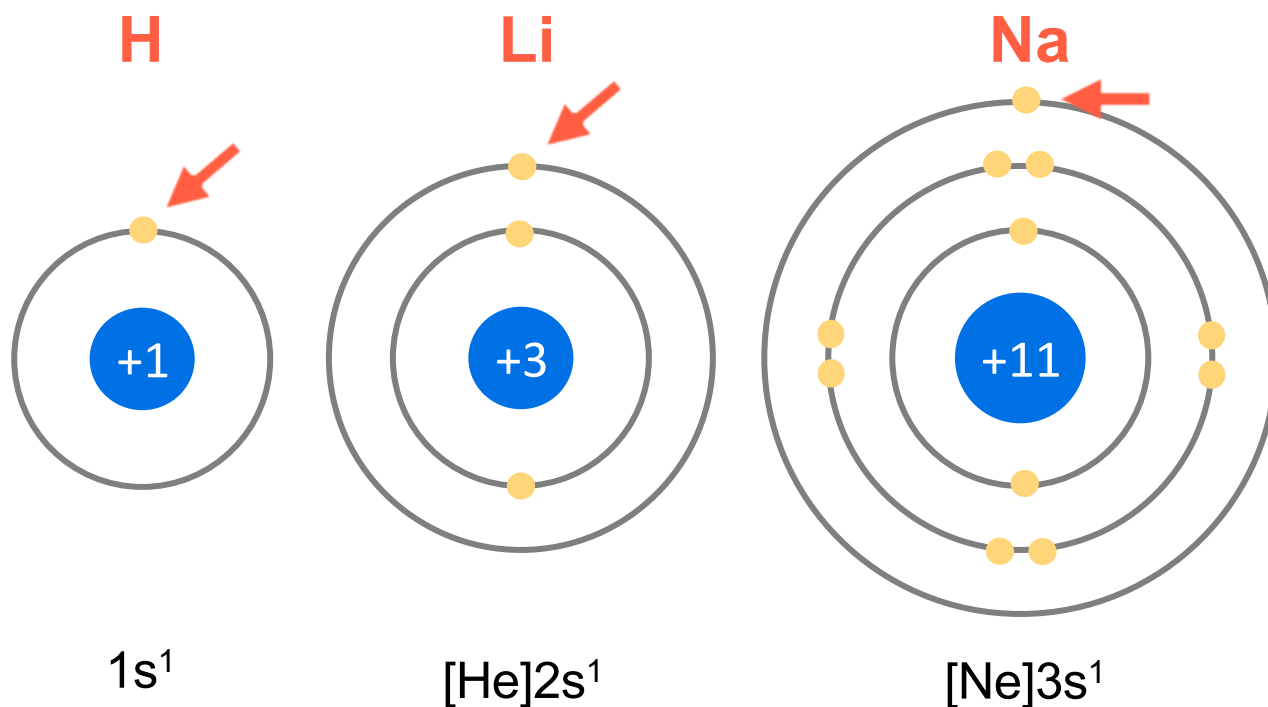
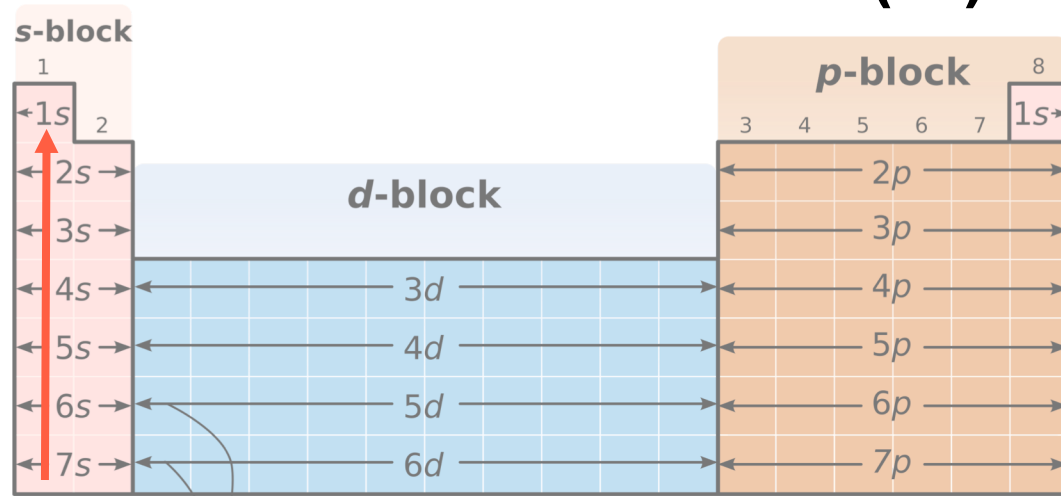

 $1s^1$ 
 $[\text{He}]2s^1$ 

Energy to remove outermost electron.

**IE decreases** down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus** → easier to remove!

# IONIZATION ENERGY (IE)

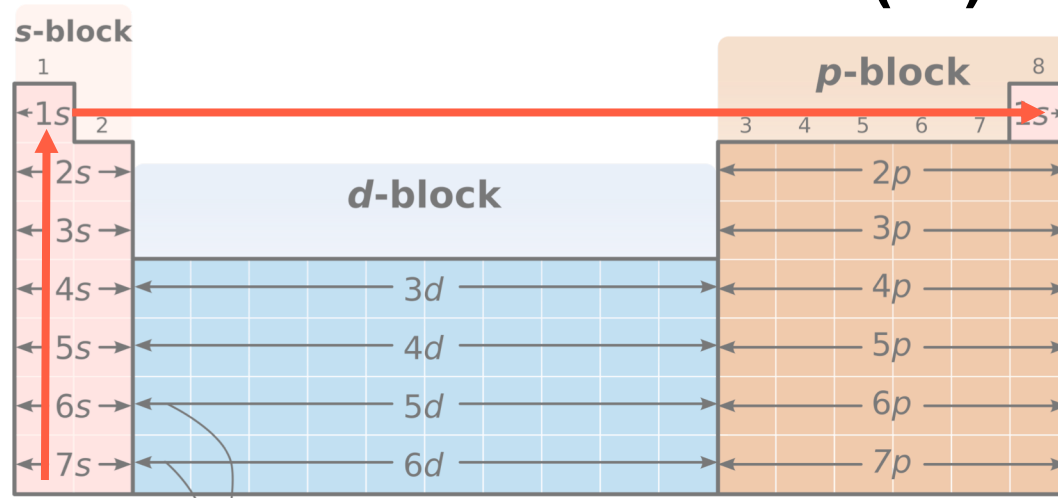


Energy to remove outermost electron.

**IE decreases** down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
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- Less pull from the positively charged **nucleus** → easier to remove!

# IONIZATION ENERGY (IE)



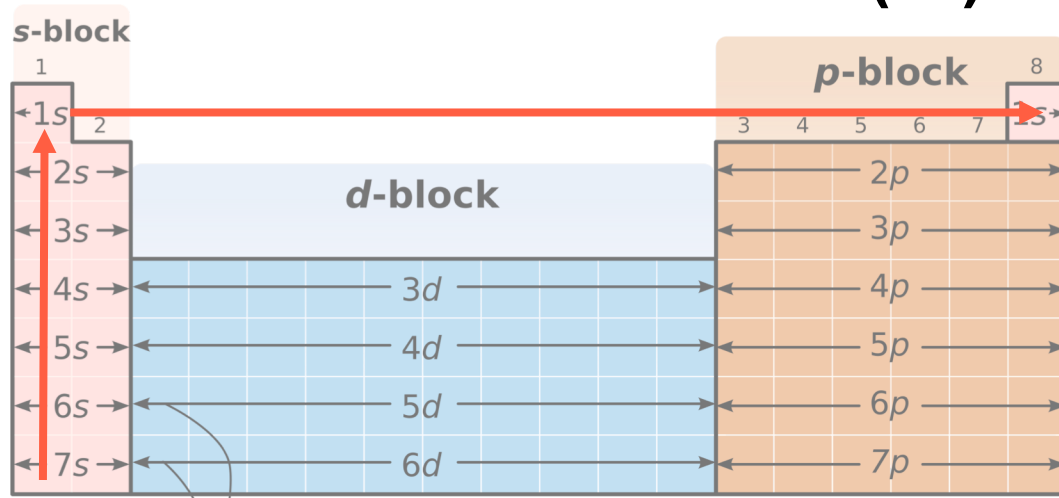
Energy to remove outermost electron.

**IE decreases** down a column:

- Adding **electrons** to larger and larger energy levels ( $n$ ).
- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus** → easier to remove!

**IE increases** across a row:

# IONIZATION ENERGY (IE)



Energy to remove outermost electron.

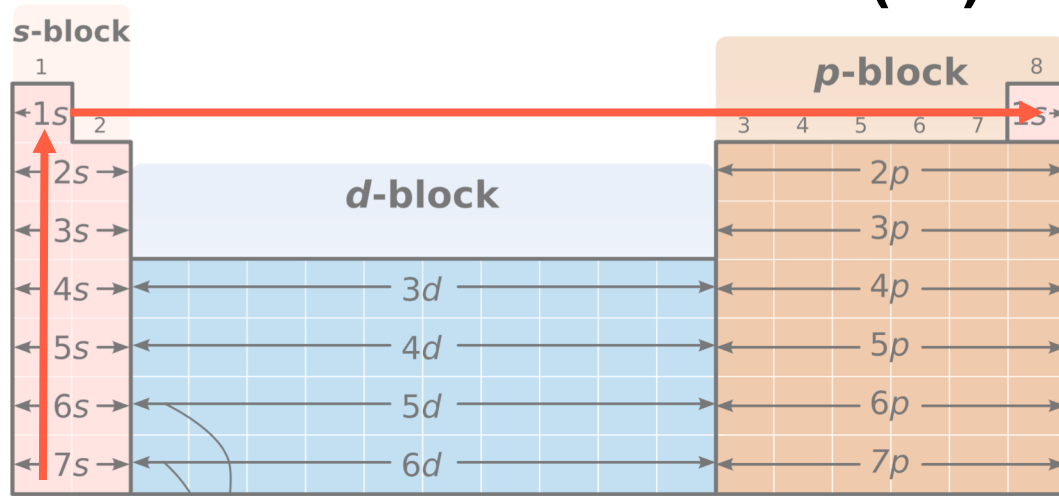
**IE decreases down a column:**

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- **Electrons** are farther and farther from the nucleus.
- Less pull from the positively charged **nucleus** → easier to remove!

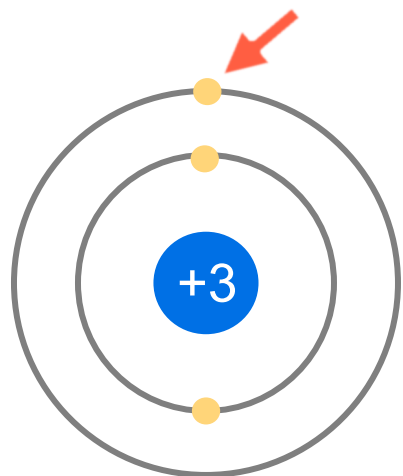
**IE increases across a row:**

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- But also have more and more **protons** (positive charge).
- **Electrons** are pulled more tightly by increased number of **protons** (i.e. greater positive charge of nucleus) → harder to remove!

# IONIZATION ENERGY (IE)



Li



[He]2s<sup>1</sup>

Energy to remove outermost electron.

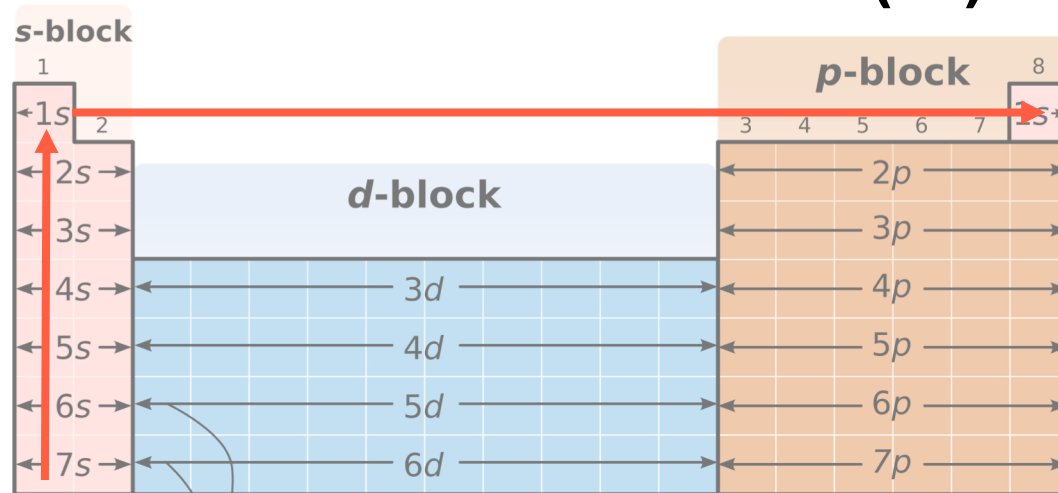
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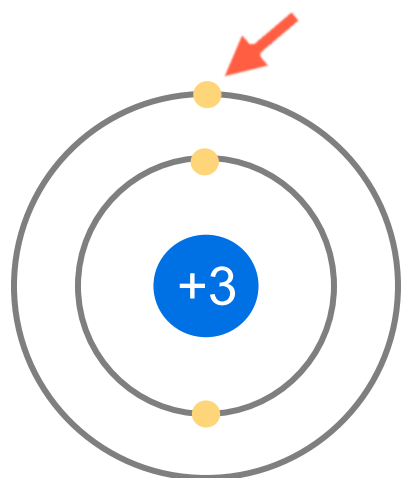
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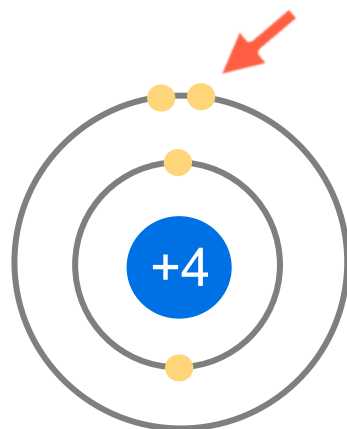
# IONIZATION ENERGY (IE)



Li

[He]2s<sup>1</sup>

Be

[He]2s<sup>2</sup>

Energy to remove outermost electron.

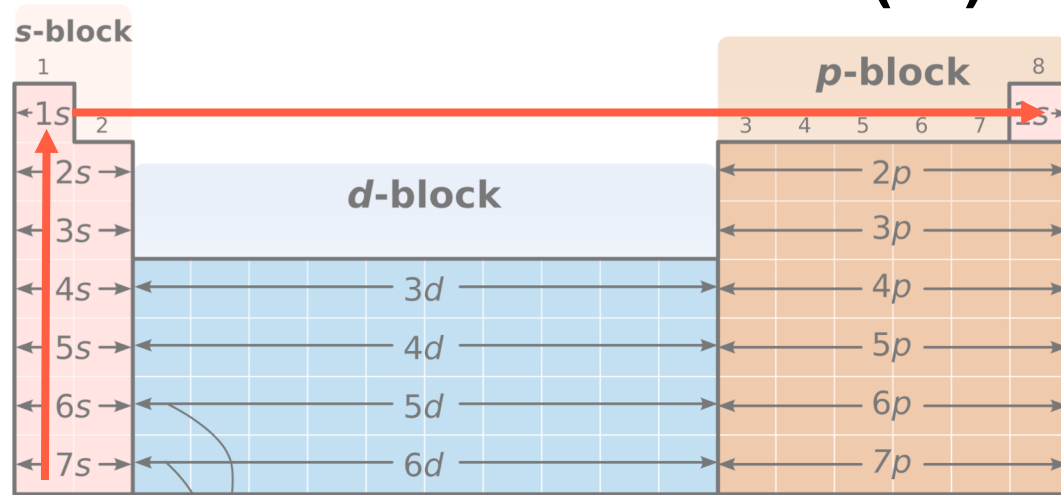
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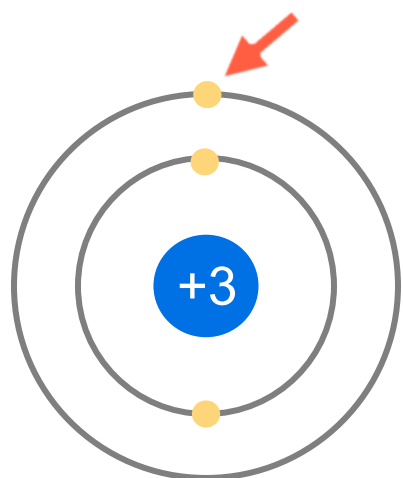
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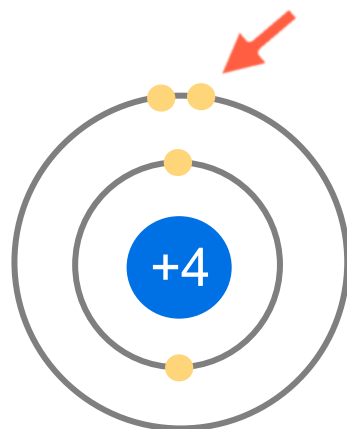
# IONIZATION ENERGY (IE)



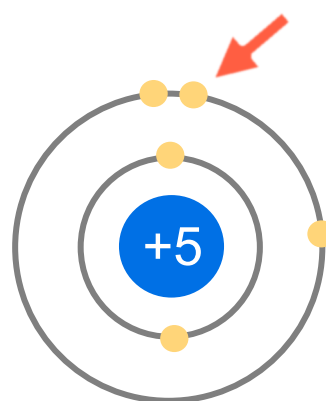
Li

[He]2s<sup>1</sup>

Be

[He]2s<sup>2</sup>

B

[He]2s<sup>2</sup>2p<sup>1</sup>

Energy to remove outermost electron.

**IE decreases down a column:**

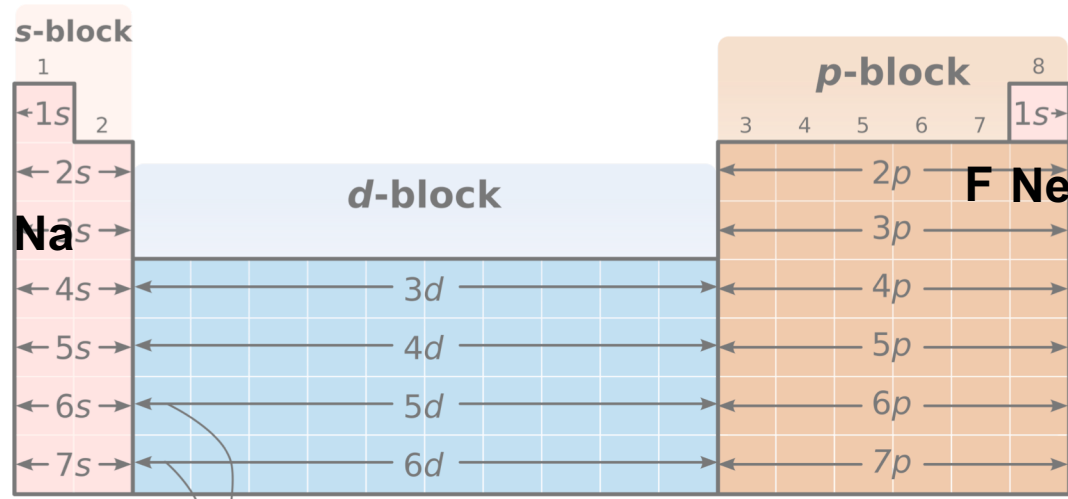
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- **Electrons** are pulled more tightly by increased number of **protons** (i.e. greater positive charge of nucleus) → harder to remove!



# WHAT TO DO WITH IONS?



$F^-$

$Ne$

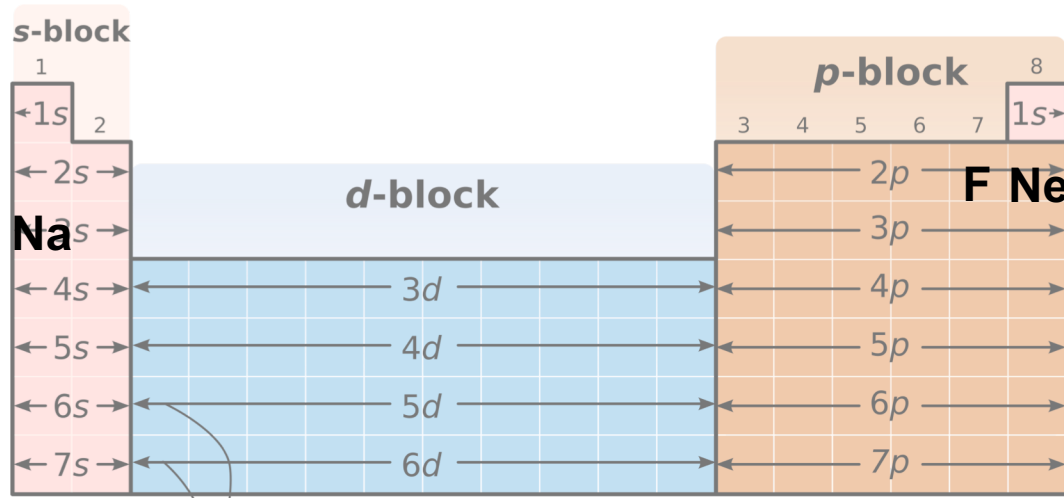
$Na^+$

Compare # of electrons & protons!

Atomic Radius/Size:

Ionization Energy

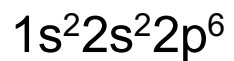
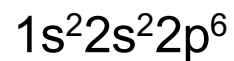
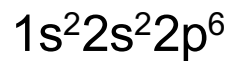
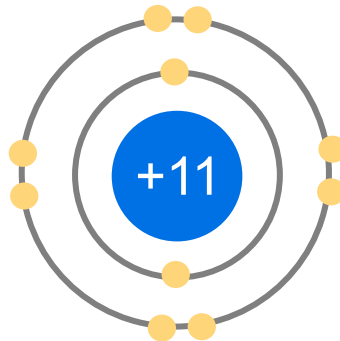
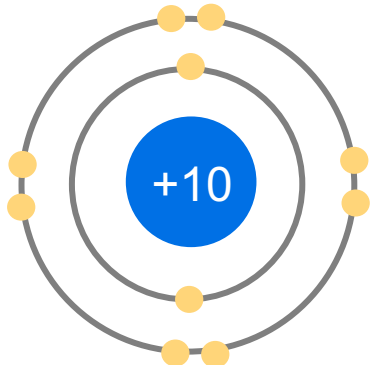
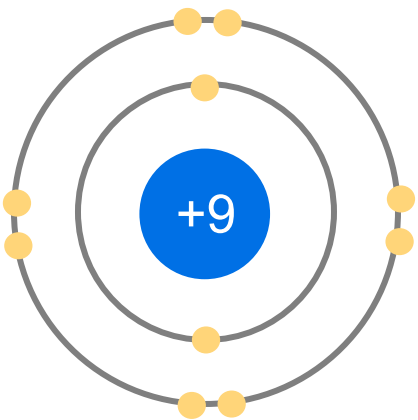
# WHAT TO DO WITH IONS?



**F<sup>-</sup>**

**Ne**

**Na<sup>+</sup>**

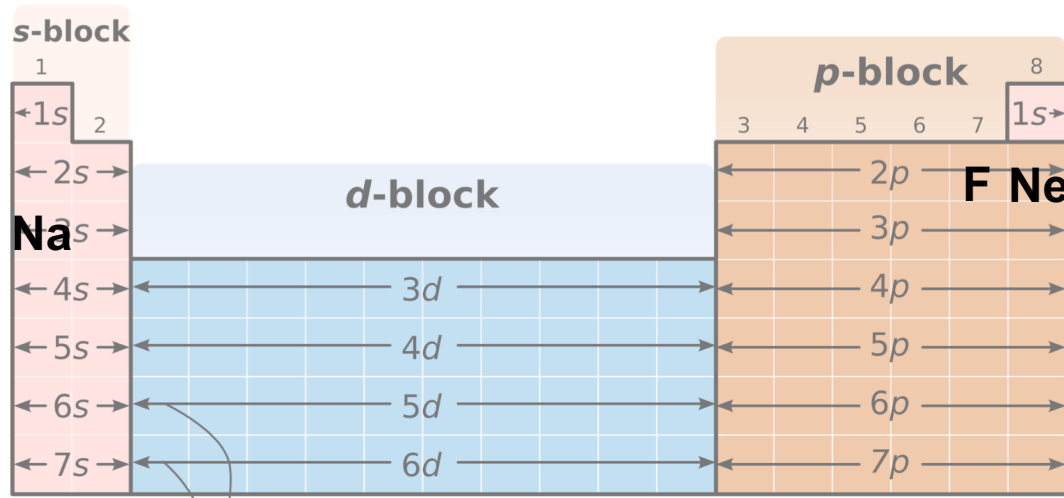


Compare # of electrons & protons!

Atomic Radius/Size:

Ionization Energy

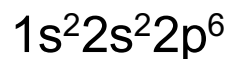
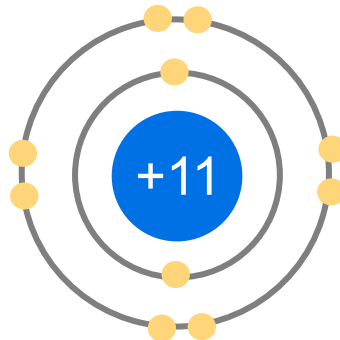
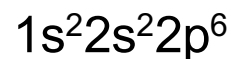
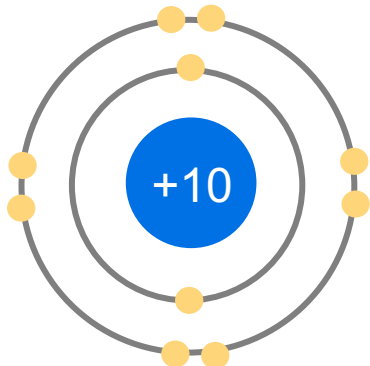
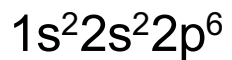
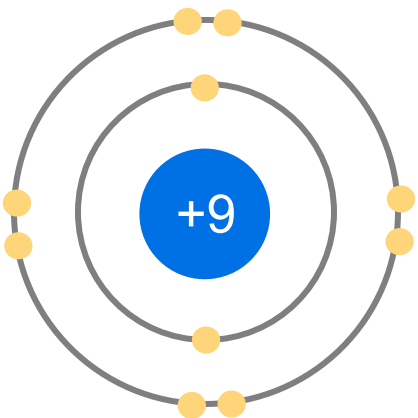
# WHAT TO DO WITH IONS?



**F<sup>-</sup>**

**Ne**

**Na<sup>+</sup>**



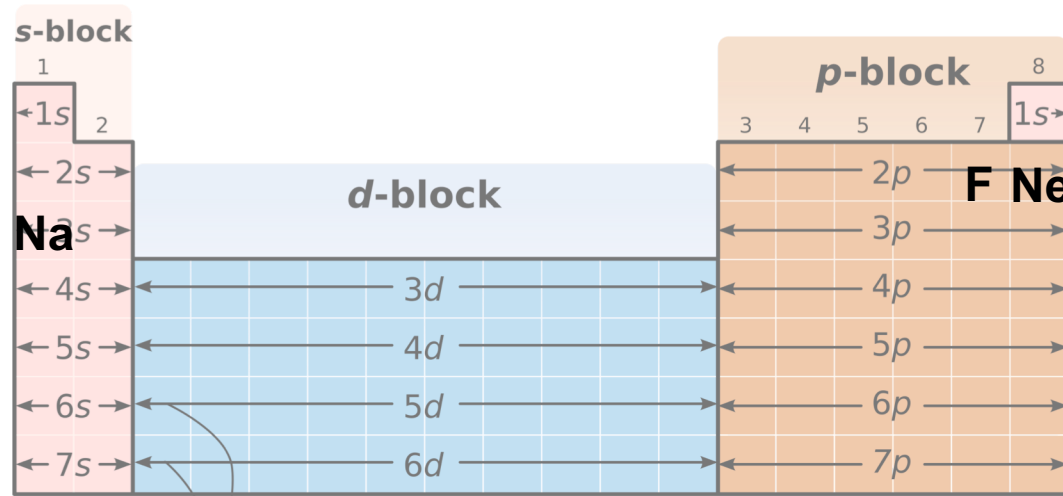
Compare # of electrons & protons!

## Atomic Radius/Size:

- Same number of **electrons**: 10 e<sup>-</sup>
- But different number of **protons**:  
 F<sup>-</sup>: +9    Ne: +10    Na<sup>+</sup>: +11
- More pull from more positively charged **nucleus**.  
 → **Na<sup>+</sup> is smallest!**

## Ionization Energy

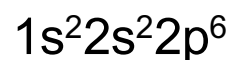
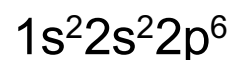
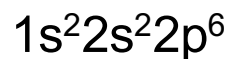
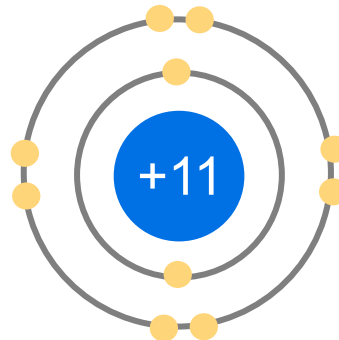
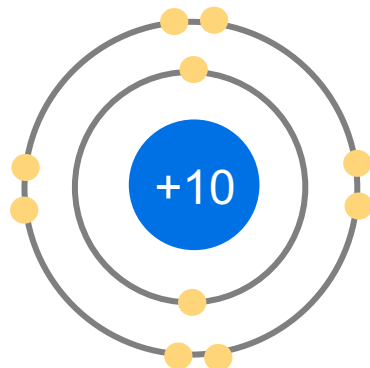
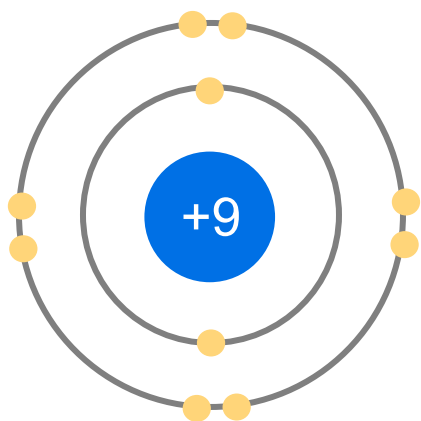
# WHAT TO DO WITH IONS?



**F<sup>-</sup>**

**Ne**

**Na<sup>+</sup>**



Compare # of electrons & protons!

## Atomic Radius/Size:

- Same number of **electrons**: 10 e<sup>-</sup>
- But different number of **protons**:  
F<sup>-</sup>: +9    Ne: +10    Na<sup>+</sup>: +11
- More pull from more positively charged **nucleus**.  
→ **Na<sup>+</sup> is smallest!**

## Ionization Energy

- Same number of **electrons**: 10 e<sup>-</sup>
- But different number of **protons**:  
F<sup>-</sup>: +9    Ne: +10    Na<sup>+</sup>: +11
- Electrons** are pulled more tightly by increased number of **protons** (i.e. greater positive charge of **nucleus**).  
→ **hardest to remove from Na<sup>+</sup>!**