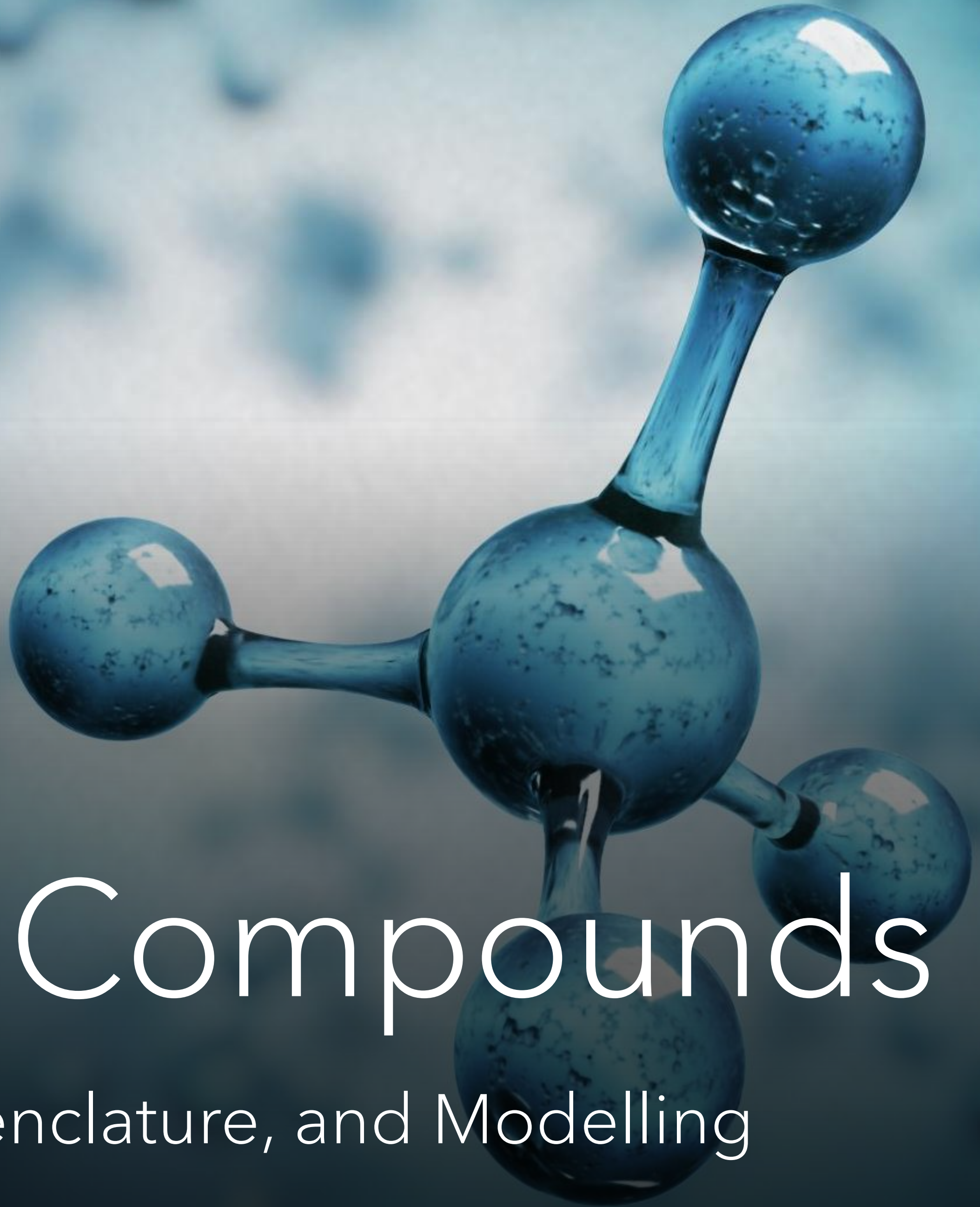


Chemical Compounds

Bond Formation, Nomenclature, and Modelling

Overview

Review: atoms and subatomic particles, ions

Modelling Atoms and Compounds

- Counting Atoms
- Bohr Models
- Lewis Diagrams

IUPAC Naming and Writing Formulas

Balanced Chemical Equations

Section 1: Review

Review

1. Why do compounds form?
2. How do you draw the Bohr model for an atom? Ion?
3. What is a valence shell? Valence electron?
4. On the periodic table, where are the metals and non-metals? What is the difference?
5. Which of these compounds are ionic? Covalent? What's the difference?
6. How do you name ionic compounds?

Review: Atoms and Subatomic Particles

Atom:

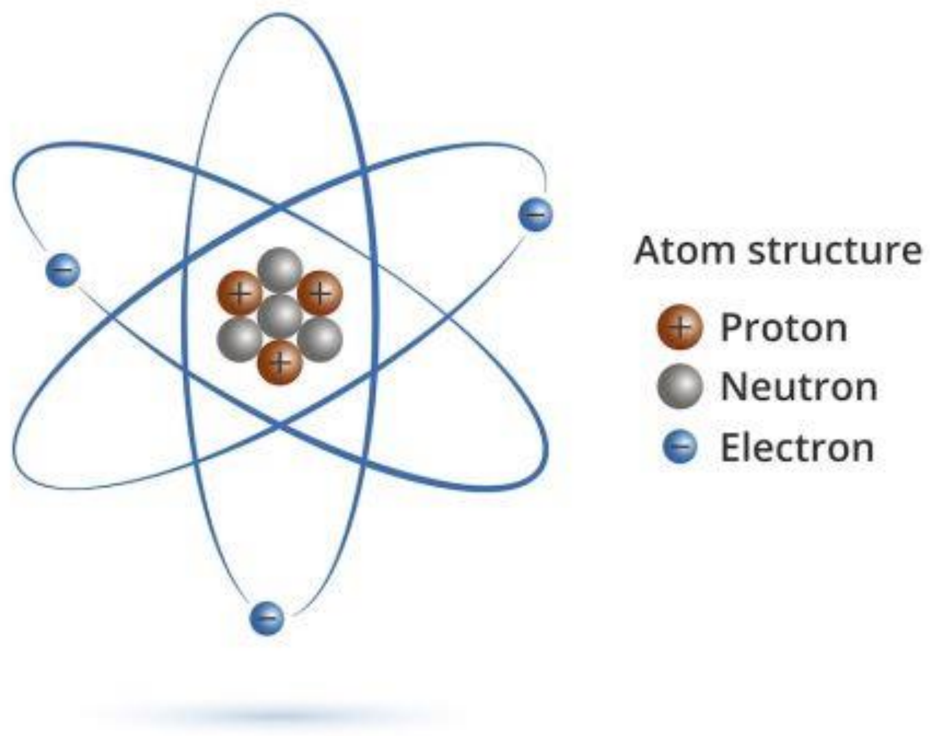
- Smallest unit of matter
- No electric charge (neutral)
- Examples:
  - Na (sodium atom)
  - O (oxygen atom)

Review: Atoms and Subatomic Particles

Proton: **positively** charged particle in the **nucleus** of an atom; has a mass of **1**

Neutron: **uncharged** particle in the **nucleus** of an atom; has a mass of **1**

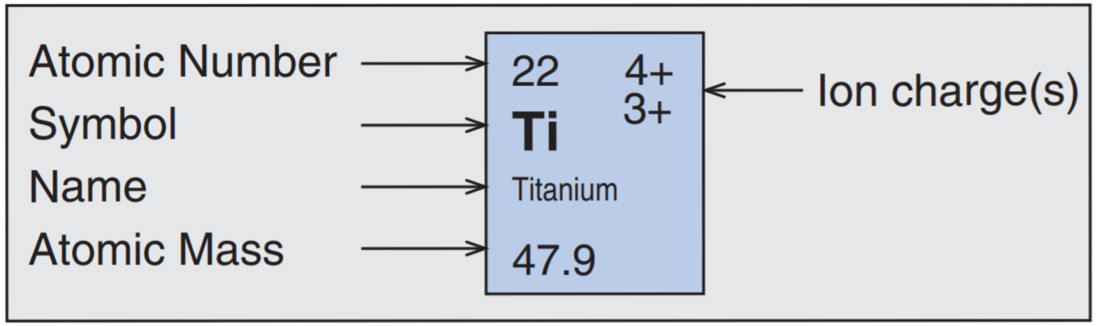
Electron: **negatively** charged particle in **energy shell** surrounding the nucleus of the atom; very tiny (mass of **0**)

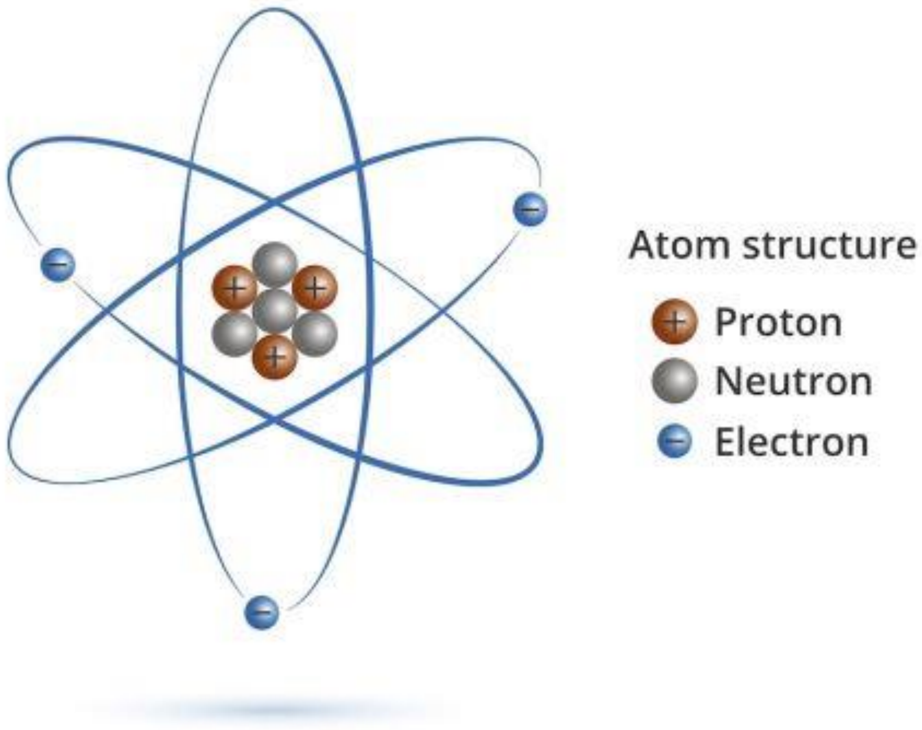


Review: Atoms and Subatomic Particles

	# protons	**# neutrons**	**# electrons**
atom (neutral)	atomic number	rounded atomic mass minus atomic number	atomic number

Review: Atoms and Subatomic Particles





For an ***atom***:

- # protons = atomic number
- # electrons = atomic number
- # neutrons =
  rounded atomic mass – atomic number

If the tenths place is a 4 or lower, round down.	32.1 → 32	65.4 → 65
If the tenths place is a 5 or higher, round up.	10.8 → 11	35.5 → 36

Review: Atoms and Subatomic Particles

As a class, calculate the number of protons, neutrons, and electrons for the following atoms:

- Al
- Mg
- B
- Ti

Practice: Atoms and Subatomic Particles

1) Complete the following table.

atom	# protons	# neutrons	# electrons
Ca	20	20	20
F	9	10	9
Cl	17	19	17
Ar	18	22	18
Zn	30	35	30

Consider the following (not on your sheet) :

2) Why are the number of protons and electrons the same for an atom? (Hint: what is the charge on an atom?)
3) Explain why you need to subtract atomic number from atomic mass to calculate the number of neutrons in an atom.

Review: Ions

Ion: an atom or molecule with an **electric charge**; formed by **gaining or losing electrons**

Examples:

- **Na^{+}** (sodium ion with 1+ charge)
- **O^{2-}** (oxygen ion with 2- charge)

Review: Ions

The Periodic Table tells you which ion(s) an atom can form.

- **Cation**: **positively** charged ion (e.g. Ca^{2+}, Cr^{3+}, NH_4^{+}); forms when electrons are **lost**
- **Anion**: **negatively** charged ion (e.g. N^{3-}, S^{2-}, PO_4^{3-}); forms when electrons are **gained**

12 2+
Mg
Magnesium
24.3

magnesium atom can **lose two electrons** to form the Mg^{2+} ion

22 4+ 3+
Ti
Titanium
47.9

multivalent metals can form **more than one ion**; example: **titanium**

16 2–
S
Sulfur
32.1

sulfur atom can **gain two electrons** to form the S^{2-} ion

10 0
Ne
Neon
20.2

6
C
Carbon
12.0

carbon and neon do not form ions

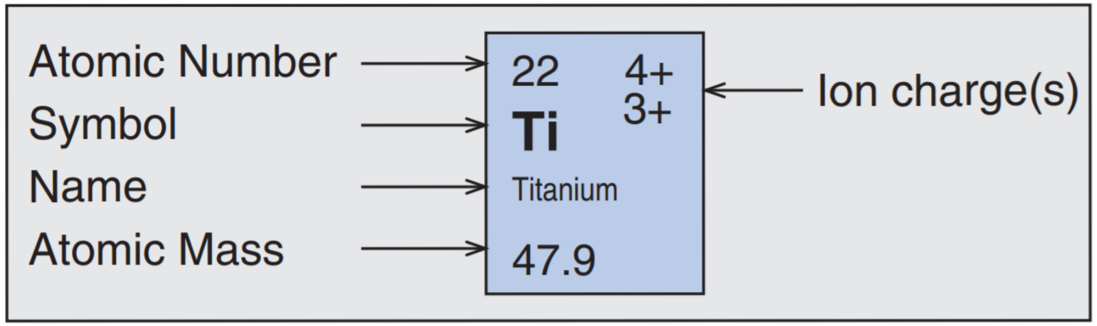
Review: Ions


CATIONs : positive ions, protons > electrons
Cats are HAPPY.
ANIONS : negative ions, protons < electrons
(onion)
Onions make you cry (negative).

Review: Atoms and Subatomic Particles

<table>
<tr><th></th><th># protons</th><th># neutrons</th><th># electrons</th></tr>
<tr><td>atom (neutral)</td><td rowspan="2">atomic number</td><td rowspan="2">rounded atomic mass minus atomic number</td><td>atomic number</td></tr>
<tr><td>ion (charged)</td><td>atomic number minus ion charge</td></tr>
</table>

Review: Ions



For an *ion:*

- # protons = atomic number
- **# electrons = atomic number – ion charge**
- # neutrons = rounded atomic mass – atomic number

Practice: Ions

	# protons	# neutrons	# electrons	Cation or Anion?
Mg^{2+}	12	12	10	cation
Ti^{3+}	22	26	19	cation
O^{2-}	8	8	10	anion
As^{3-}	33	42	36	anion
phosphorus ion	15	16	18	anion
lithium ion	3	4	2	cation
manganese(IV) ion	25	30	21	cation
cobalt(III) ion	27	32	24	cation

Polyatomic Ions

NAMES, FORMULAE AND CHARGES OF SOME POLYATOMIC IONS

Positive Ions		Negative Ions	
NH_4^+	Ammonium	CH_3COO^-	Acetate
		CO_3^{2-}	Carbonate
		ClO_3^-	Chlorate
		ClO_2^-	Chlorite
		CrO_4^{2-}	Chromate
		CN^-	Cyanide
		$Cr_2O_7^{2-}$	Dichromate
		HCO_3^-	Hydrogen carbonate, bicarbonate
		HSO_4^-	Hydrogen sulfate, bisulfate
		HS^-	Hydrogen sulfide, bisulfide

A **polyatomic ion** is a **group** of covalently bonded atoms with a charge.

E.g. NH_4 (nitrogen tetrahydride) can lose an electron to become NH_4^+ (ammonium ion)

Practice: Atoms and Ions

3. Why do atoms and ions have the same number of protons and neutrons, but different numbers of electrons?
4. Why do ions never have the same number of protons as electrons?
5. To form an anion, does an atom have to gain or lose electrons? Why?
6. When a calcium atom becomes an ion, does it have to gain or lose electrons? How many?

Practice: Atoms and Ions

7. Is the chlorine ion a cation or an anion? Does it form by gaining or losing electrons?
8. Is Cr^{3+} a cation or anion?
9. Does arsenic form an ion by gaining or losing electrons? How many? How do you know?
10. Why do we call manganese a multivalent element? List 3 other multivalent elements.

Practice: Atoms and Ions

	# protons	# neutrons	# electrons	Type (Atom, Cation, or Anion?)
N	7	7	7	atom
Br^-	35	45	36	anion
Zn^{2+}	30	35	28	cation
Li	3	4	3	atom
aluminum	13	14	13	atom
calcium ion	20	20	18	cation
nickel(III) ion	28	31	25	cation
potassium	19	20	19	atom

Section 2: Modelling Atoms and Compounds

Modelling Atoms and Compounds

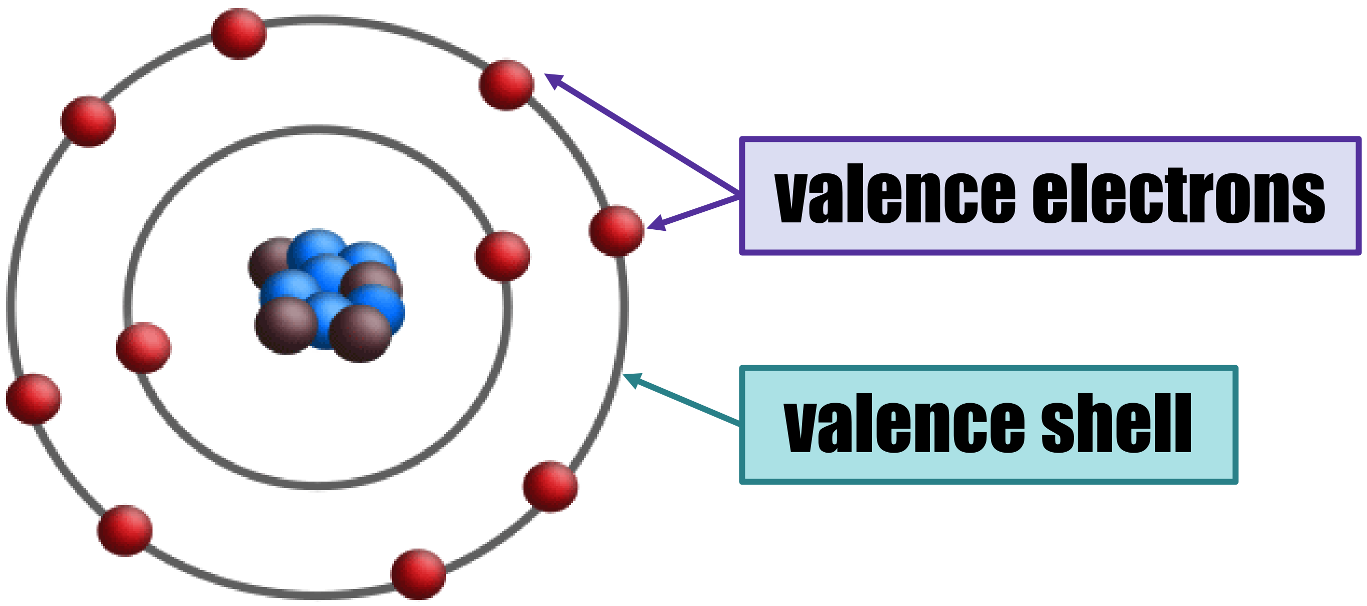
- Introduction to Chemical Compounds
- Counting Atoms
- Bohr Models of Atoms, Ionic Compounds, and Covalent Compounds
- Lewis Diagrams of Atoms, Ionic Compounds, and Covalent Compounds

Introduction to Chemical Compounds

What are compounds? Why do they form? (textbook pgs ~120-124)

Achieving Stability Through Nobility

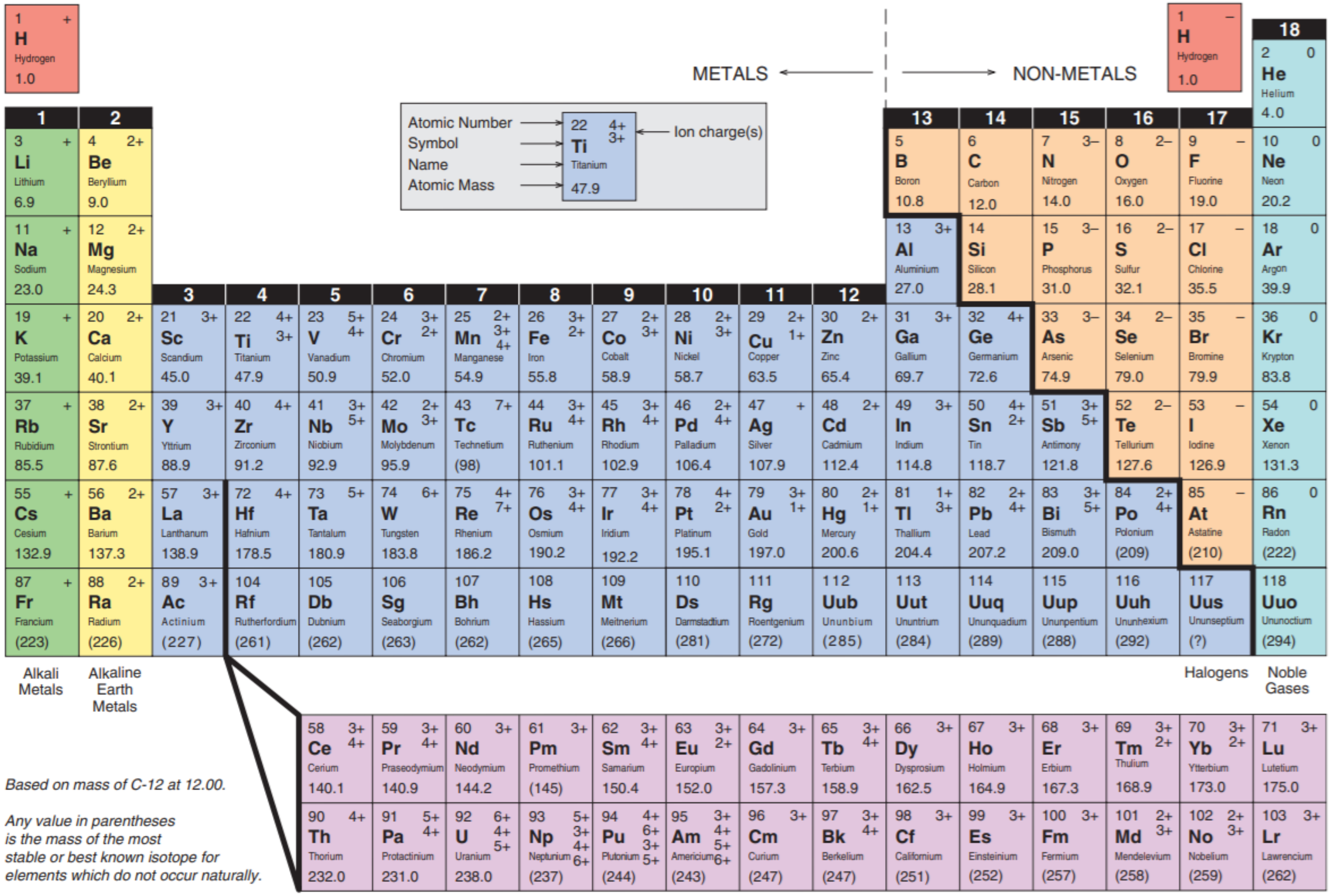
- The **valence shell** is the **outermost shell containing electrons**. Electrons in this shell are called **valence electrons**.
- A **stable atom** has a full valence shell.



Achieving Stability Through Nobility

- The **valence shell** is the **outermost shell containing electrons**. Electrons in this shell are called **valence electrons**.
- A stable atom has a full valence shell.
- Atoms react to form **compounds** (group of atoms bonded together) to become stable by having a **full valence shell**.
  - **Ionic compound**: formed when atoms **gain or lose electrons** (e.g. NaCl, K_2O)
  - **Covalent compound**: formed when atoms **share electrons** (e.g. CO_2, H_2O_2)

Achieving Stability Through Nobility



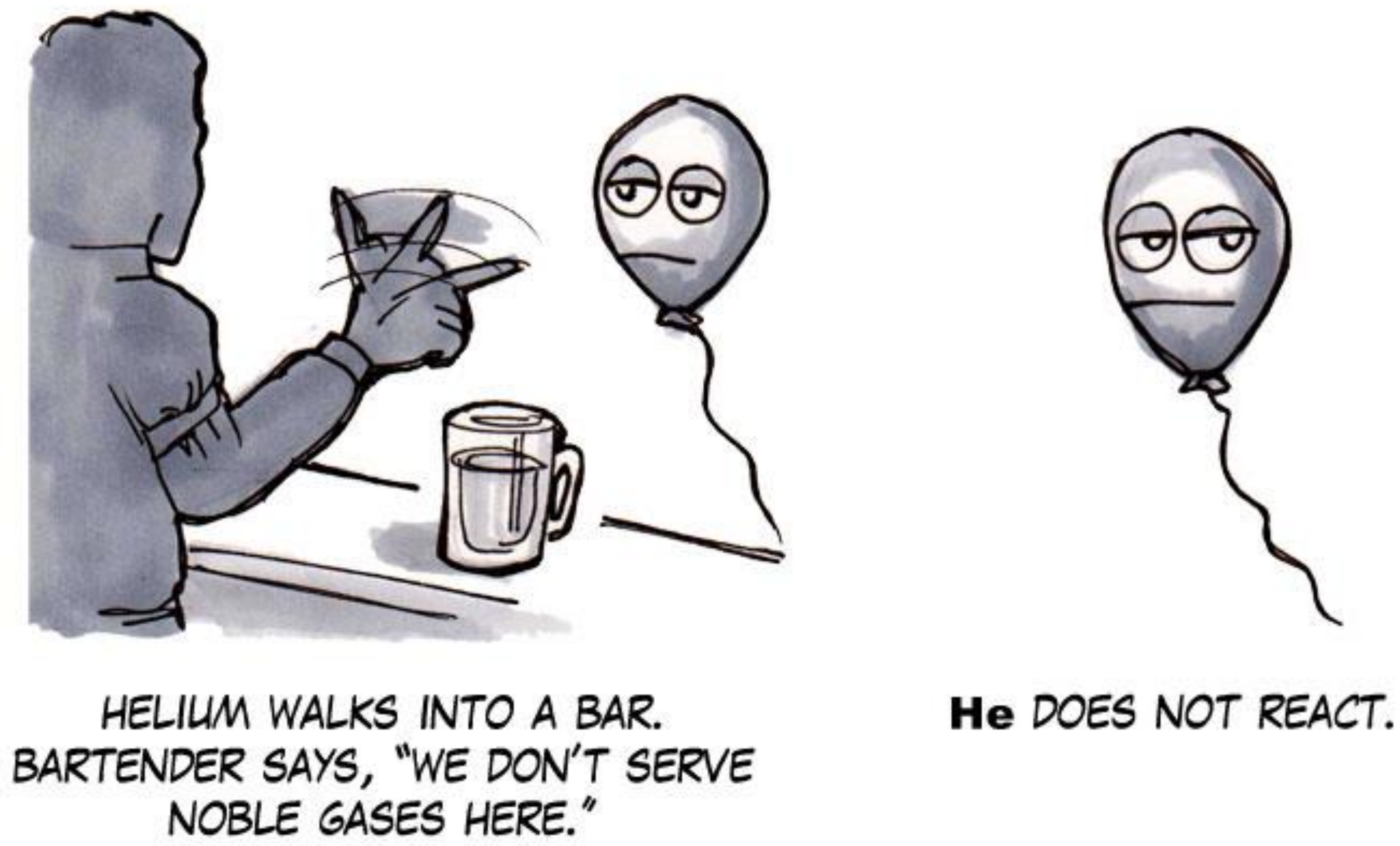
Valence electrons can explain reactivity.

The **closer** an atom is to a full valence shell, the more **reactive** it is.

Alkali metals and halogens extremely reactive.

Alkaline earth metals and Group 16 elements are very reactive.

Achieving Stability Through Nobility



Valence electrons can explain reactivity.

Noble gases already have a **<u>full valence shell</u>**: they do not react with other elements.

Practice

Identify the following as **atoms/pure elements**, **ions**, or **compounds**.
BONUS: identify any cations, anions, and polyatomic ions.

1. Na
2. $TiCl_3$
3. CH_4
4. Cu
5. Fe^{3+}
6. H_2O
7. H_2
8. Fe
9. O^{2-}
10. I_2
11. $Ni(OH)_3$
12. Mg
13. $Ca(OH)_2$
14. Mn
15. HSO_4^-
16. Cu^+
17. VS_2
18. NO
19. MgO_2
20. Pt^{4+}
21. Be
22. ClO_2^-
23. CCl_4
24. Cl_2

Practice

Identify the following as **atoms/pure elements**, **ions**, or **compounds**.
BONUS: identify any cations, anions, and polyatomic ions.

1. Na
2. $TiCl_3$
3. CH_4
4. Cu
5. Fe^{3+}
6. H_2O
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13. $Ca(OH)_2$
14. Mn
15. HSO_4^-
16. Cu^+
17. VS_2
18. NO
19. MgO_2
20. Pt^{4+}
21. Be
22. ClO_2^-
23. CCl_4
24. Cl_2

Cations: Fe^{3+}, Cu^+, Pt^{4+}. Anions: O^{2-}, HSO_4^-, ClO_2^-. Polyatomic: HSO_4^-, ClO_2^-

Counting Atoms

See "AcCounting for Atoms" worksheet and answer key.

Bohr Models

(textbook pgs ~120-124)

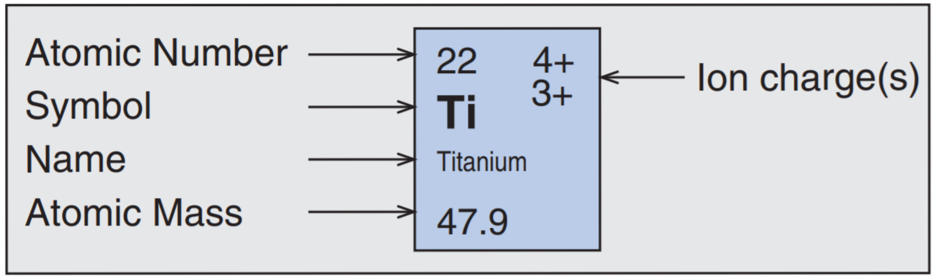
Drawing Bohr Models of Atoms and Ions

1. Calculate the number of protons, neutrons, electrons.
2. In the nucleus:
   - **Element symbol**
   - **# protons, # neutrons**
3. Draw the electrons in energy shells:
   - Max electrons per shell from inside to outside: **2, 8, 8, 18**
   - (Except in first shell), electrons are filled *starting at top*, going *clockwise*, singly at first then paired
4. Ions only:
   - Add **square brackets** and **ion charge** from periodic table

Drawing Bohr Models of Atoms and Ions

1. Calculate the number of protons, neutrons, electrons.

	protons	neutrons	electrons
Atom	atomic number	*rounded* atomic mass minus atomic number	atomic number
Ion	atomic number	*rounded* atomic mass minus atomic number	atomic number minus ionic charge

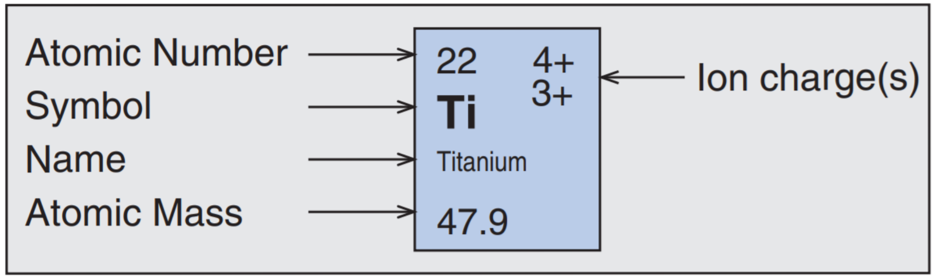


		p	n	e
11 + **Na** Sodium 23.0	Na			
	Na^{+}			
12 2+ **Mg** Magnesium 24.3	Mg			
	Mg^{2+}			
8 2– **O** Oxygen 16.0	O			
	O^{2-}			
17 – **Cl** Chlorine 35.5	Cl			
	Cl^{-}			

Drawing Bohr Models of Atoms and Ions

1. Calculate the number of protons, neutrons, electrons.

	protons	neutrons	electrons
Atom	atomic number	*rounded* atomic mass minus atomic number	atomic number
Ion	atomic number	*rounded* atomic mass minus atomic number	atomic number minus ionic charge



		p	n	e
11 + **Na** Sodium 23.0	Na	11	23-11=12	11
	Na^{+}	11	23-11=12	11-(+1)=10
12 2+ **Mg** Magnesium 24.3	Mg	12	24-12=12	12
	Mg^{2+}	12	24-12=12	12-(+2)=10
8 2– **O** Oxygen 16.0	O	8	16-8=8	8
	O^{2-}	8	16-8=8	8-(-2)=10
17 – **Cl** Chlorine 35.5	Cl	17	36-17=19	17
	Cl^{-}	17	36-17=19	18

Drawing Bohr Models of Atoms and Ions

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Drawing Bohr Models of Atoms and Ions

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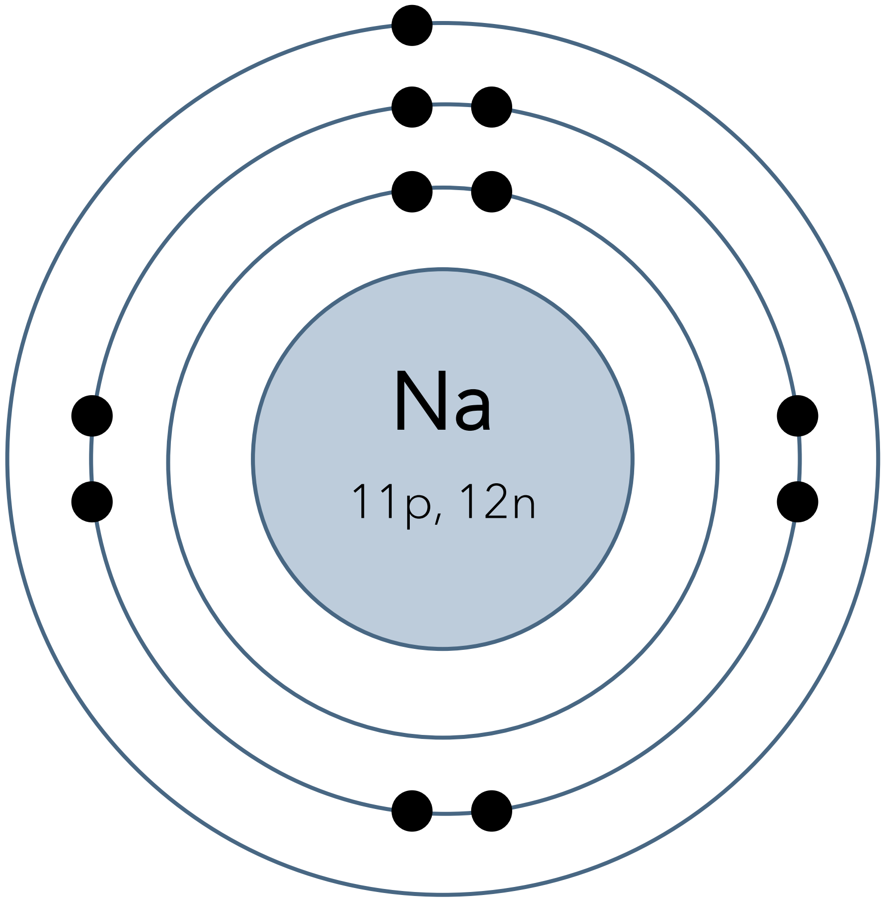
4. Ions only:
   - Add square brackets and ion charge from periodic table

	p	n	e
Na	11	23-11=12	11

Example: sodium atom



Drawing Bohr Models of Atoms and Ions

1. Calculate the number of protons, neutrons, electrons.
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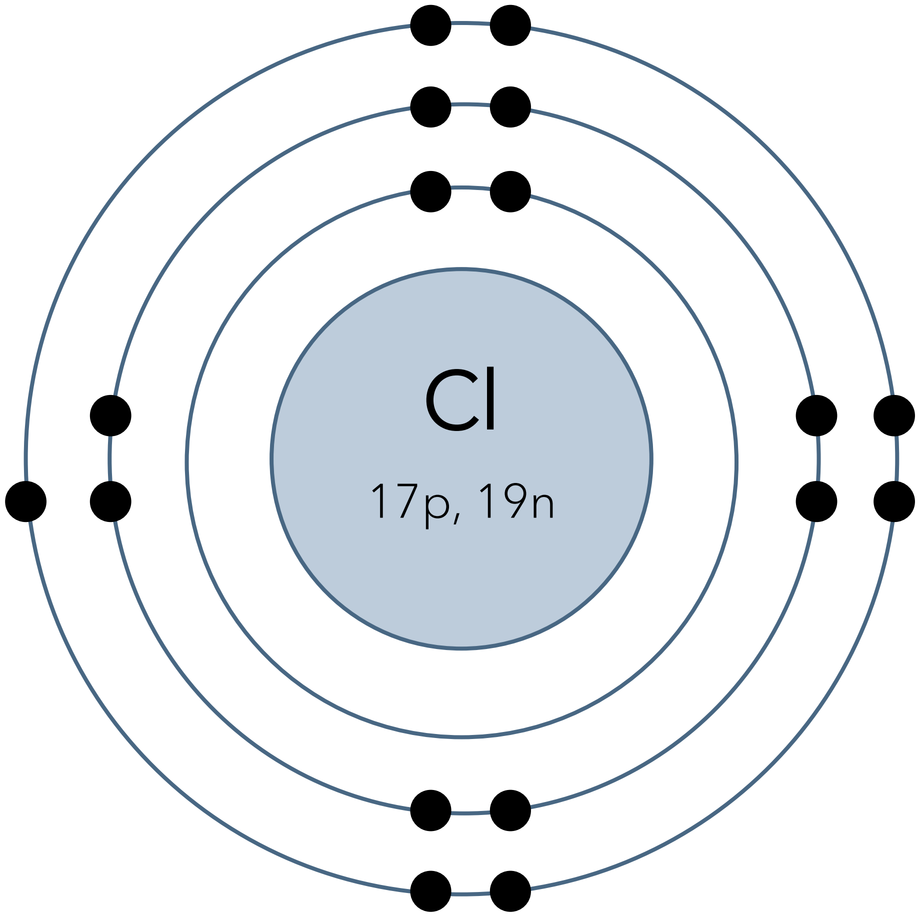
4. Ions only:
   - Add square brackets and ion charge from periodic table

	p	n	e
Cl	17	36-17=19	17

Example: chlorine atom



Drawing Bohr Models of Atoms and Ions

1. Calculate the number of protons, neutrons, electrons.
2. In the nucleus:
   - Element symbol
   - # protons, # neutrons
3. Draw the electrons in energy shells:
   - Max electrons per shell from inside to outside: 2, 8, 8, 18
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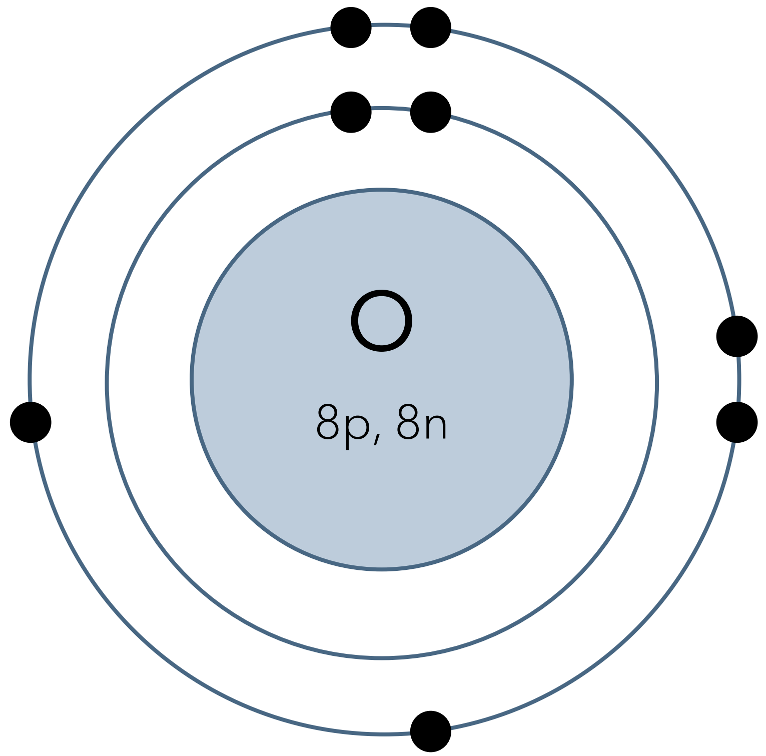
4. Ions only:
   - Add square brackets and ion charge from periodic table

	p	n	e
O	8	16-8=8	8

Example: oxygen atom



Drawing Bohr Models of Atoms and Ions

1. Calculate the number of protons, neutrons, electrons.
2. In the nucleus:
   - Element symbol
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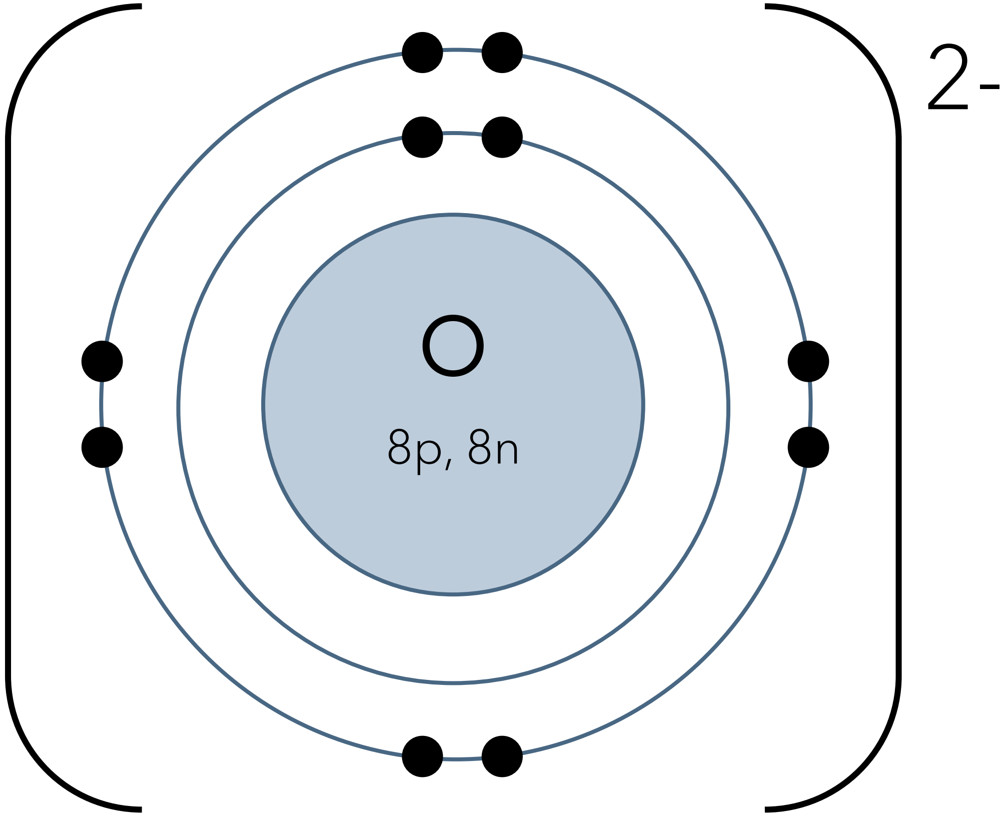
3. Draw the electrons in energy shells:
   - Max electrons per shell from inside to outside: 2, 8, 8, 18
   - (Except in first shell), electrons are filled starting at top, going clockwise, singly at first then paired
4. Ions only:
   - Add square brackets and ion charge from periodic table

	p	n	e
O^{2-}	8	16-8=8	8-(-2)=10

Note: subtracting a negative is the same as adding.

Example: oxygen ion

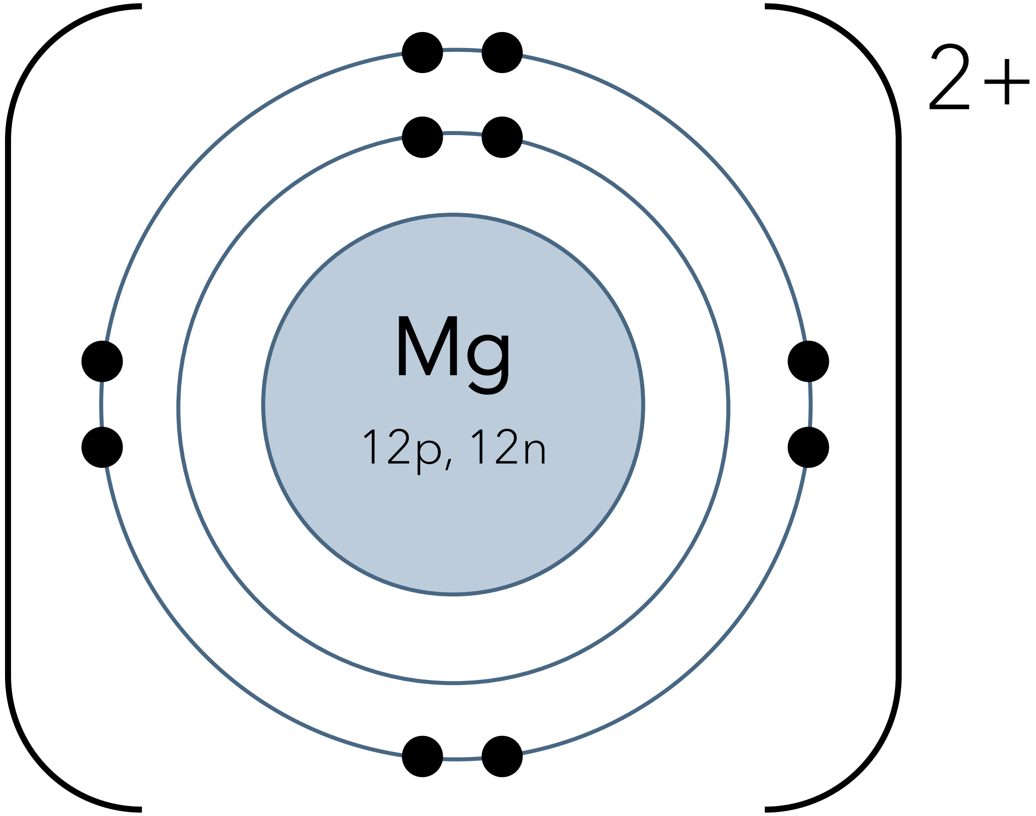


Drawing Bohr Models of Atoms and Ions

1. Calculate the number of protons, neutrons, electrons.
2. In the nucleus:
   - Element symbol
   - # protons, # neutrons
3. Draw the electrons in energy shells:
   - Max electrons per shell from inside to outside: 2, 8, 8, 18
   - (Except in first shell), electrons are filled starting at top, going clockwise, singly at first then paired
4. Ions only:
   - Add square brackets and ion charge from periodic table

	p	n	e
Mg^{2+}	12	24-12=12	12-(+2)=10

Example: magnesium ion

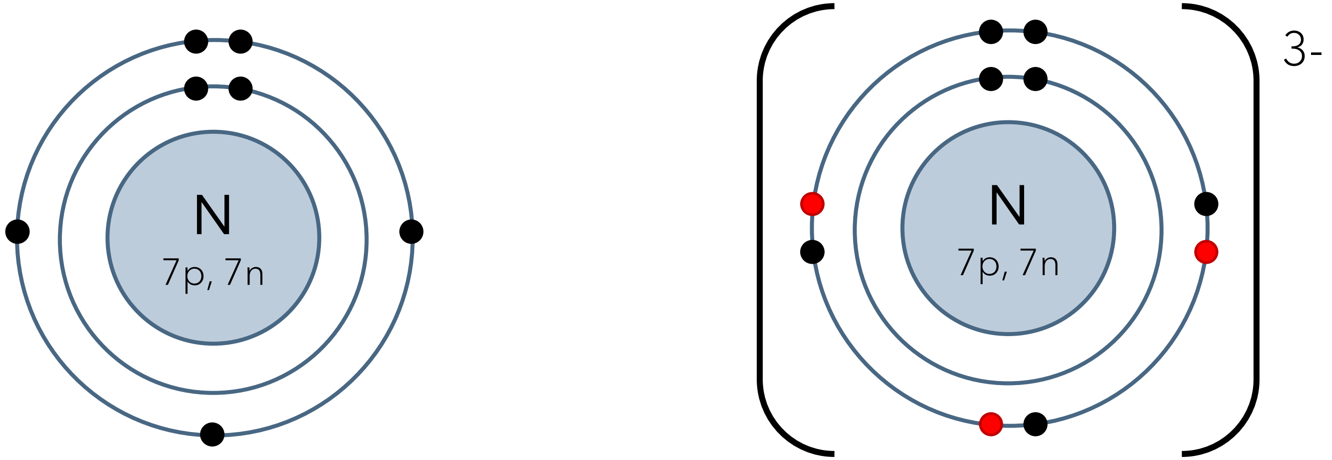


Ion Formation

Warm-up: Draw the Bohr models of the nitrogen atom and the nitrogen ion.

nitrogen atom (neutral)

nitrogen ion (3- charge)

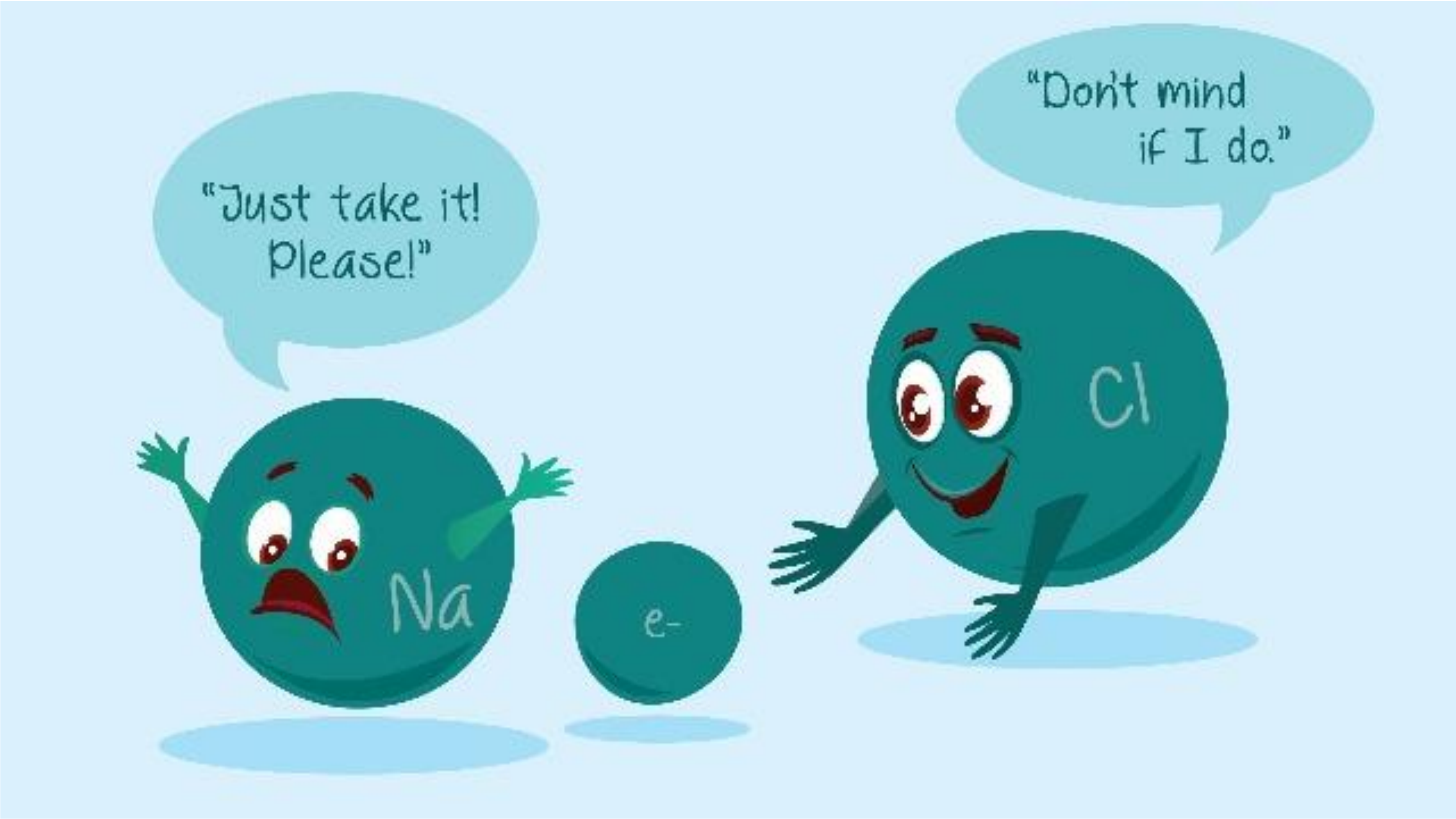


Where do these extra electrons come from?

Ion Formation

- Atoms form ions to have a **full valence shell**, just like the noble gases have.
- Electrons are negatively charged. When electrons are added, atoms become **negatively charged anions**. When electrons are taken away, atoms become **positively charged cations**.

Ionic Compound Formation



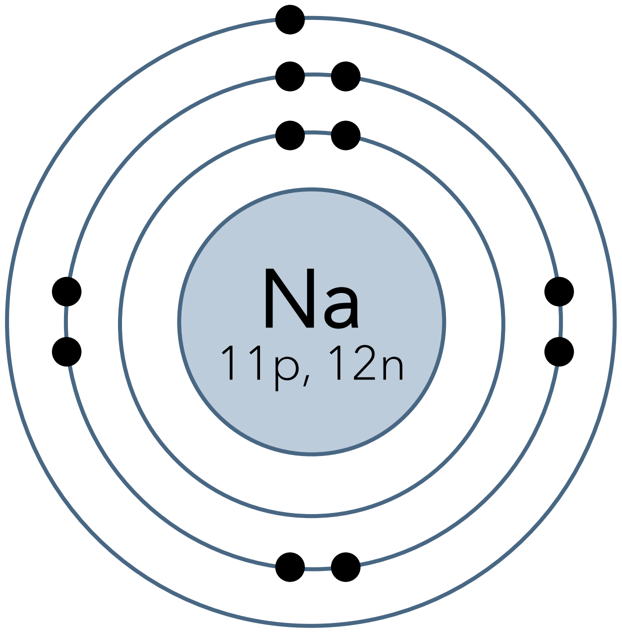
https://www.technologynetworks.com/analysis/articles/cation-vs-anion-definition-chart-and-the-periodic-table-322863

Ionic Compound Formation

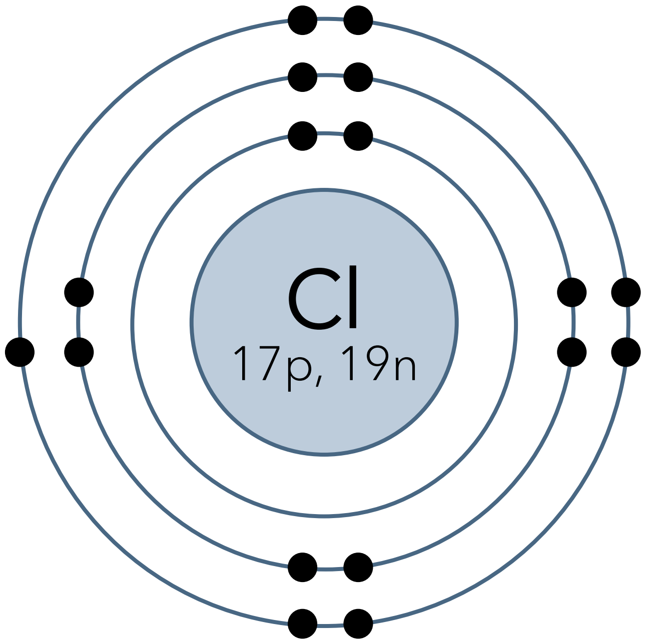
Ionic compound:

- Forms when **electrons are transferred** from one atom to another
- Involves a **cation (usually metal)** and an **anion (usually non-metal)** being chemically bonded together
- Examples of ionic compounds:
  - $MgCl_2$
  - KBr
  - Ti_2O_3
  - $Mg(ClO_3)_2$

Ionic Compound Formation (NaCl)



sodium atom (neutral)

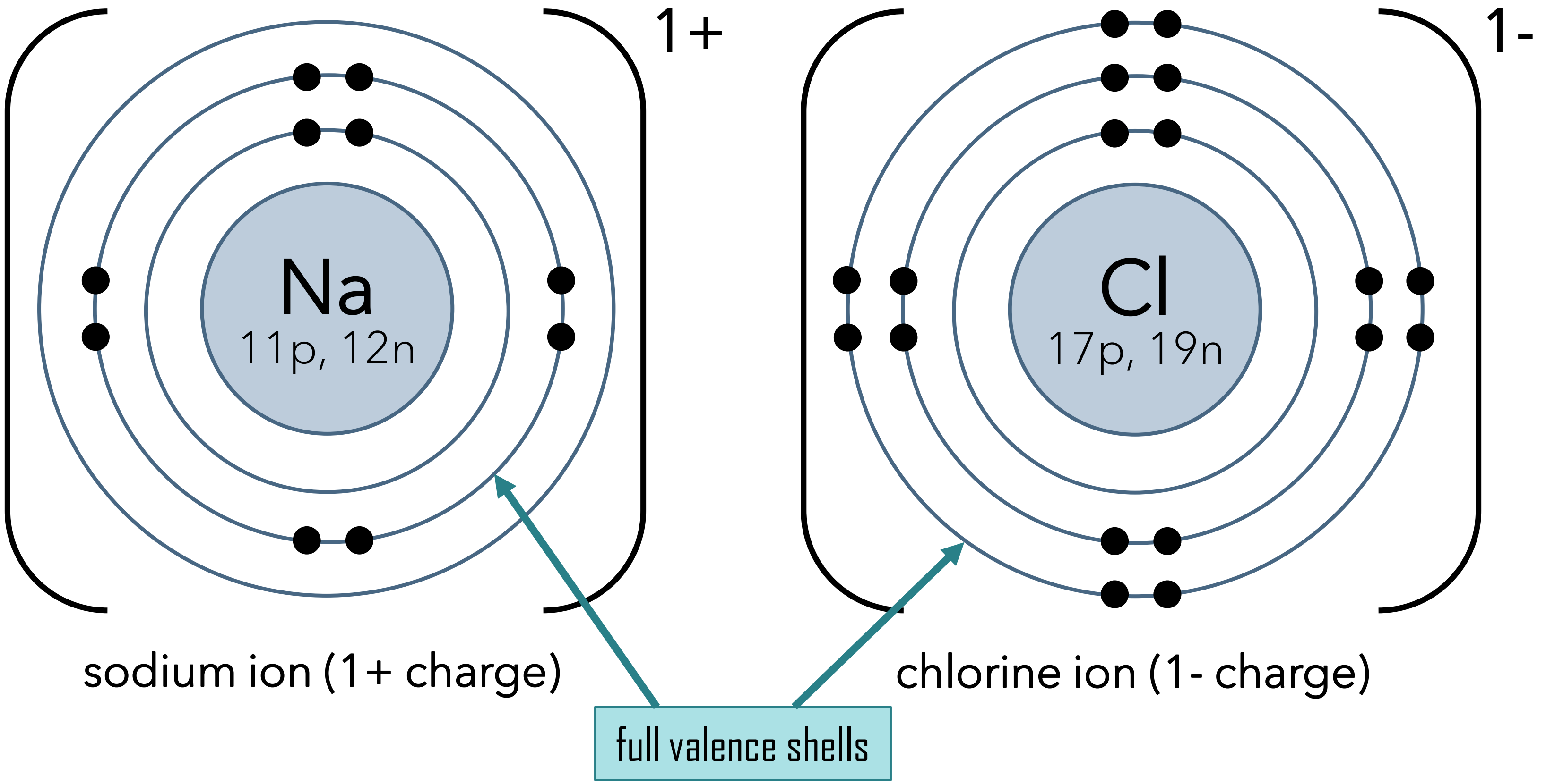


chlorine atom (neutral)

In order to get full valence shells:

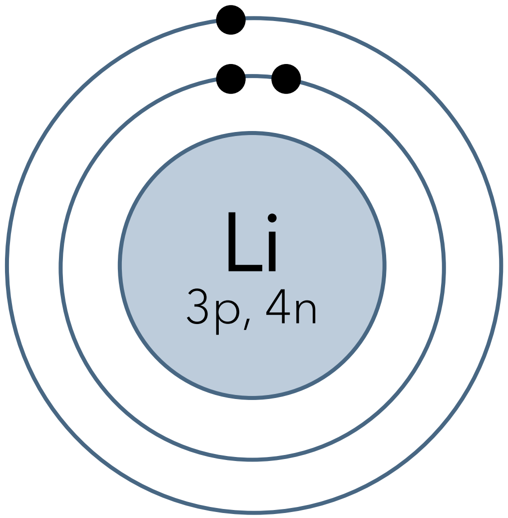
- Na needs to **lose 1** electron.
- Cl needs to **gain 1** electron.

Ionic Compound Formation (NaCl)

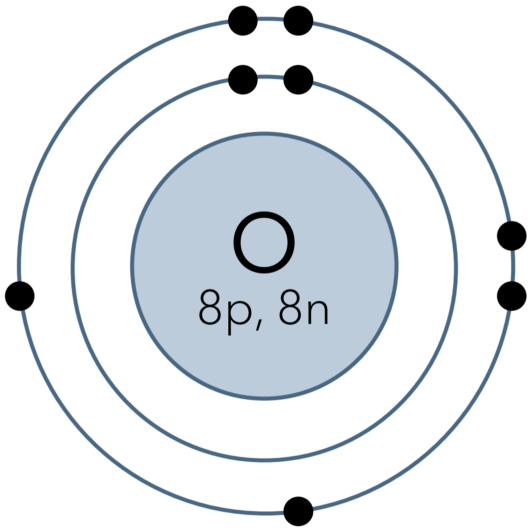


This ionic compound is **NaCl** (sodium chloride). It has one Na^+ ion and one Cl^- ion.

Ionic Compound Formation (Li_2O)



lithium atom (neutral)



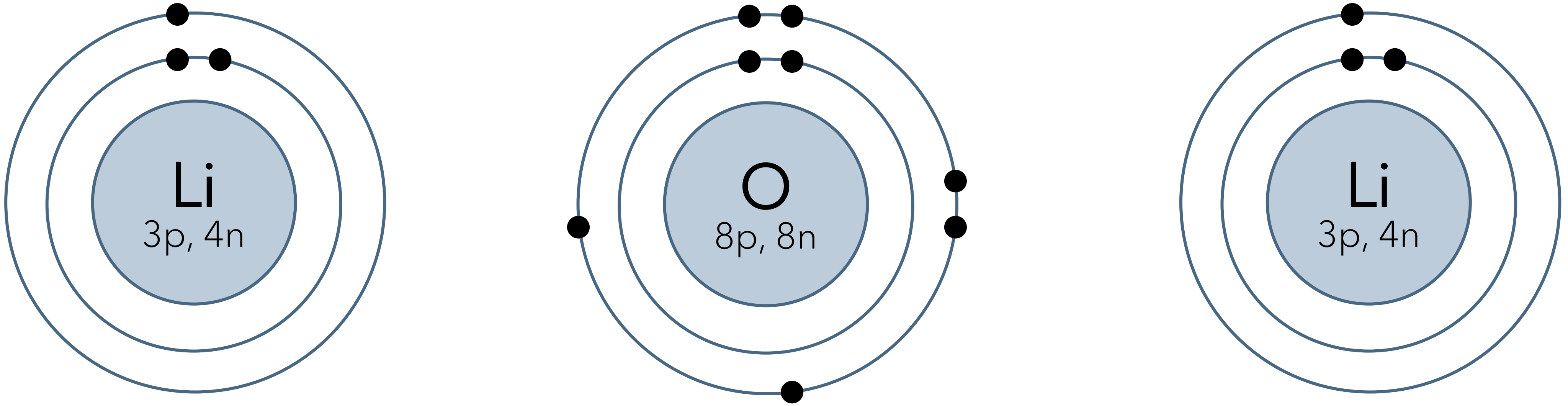
oxygen atom (neutral)

- Li needs to **lose 1** electron.
- O needs to **gain 2** electrons.

Problem: Electron numbers not balanced.

Solution: The compound needs two lithium ions!

Ionic Compound Formation (Li_2O)

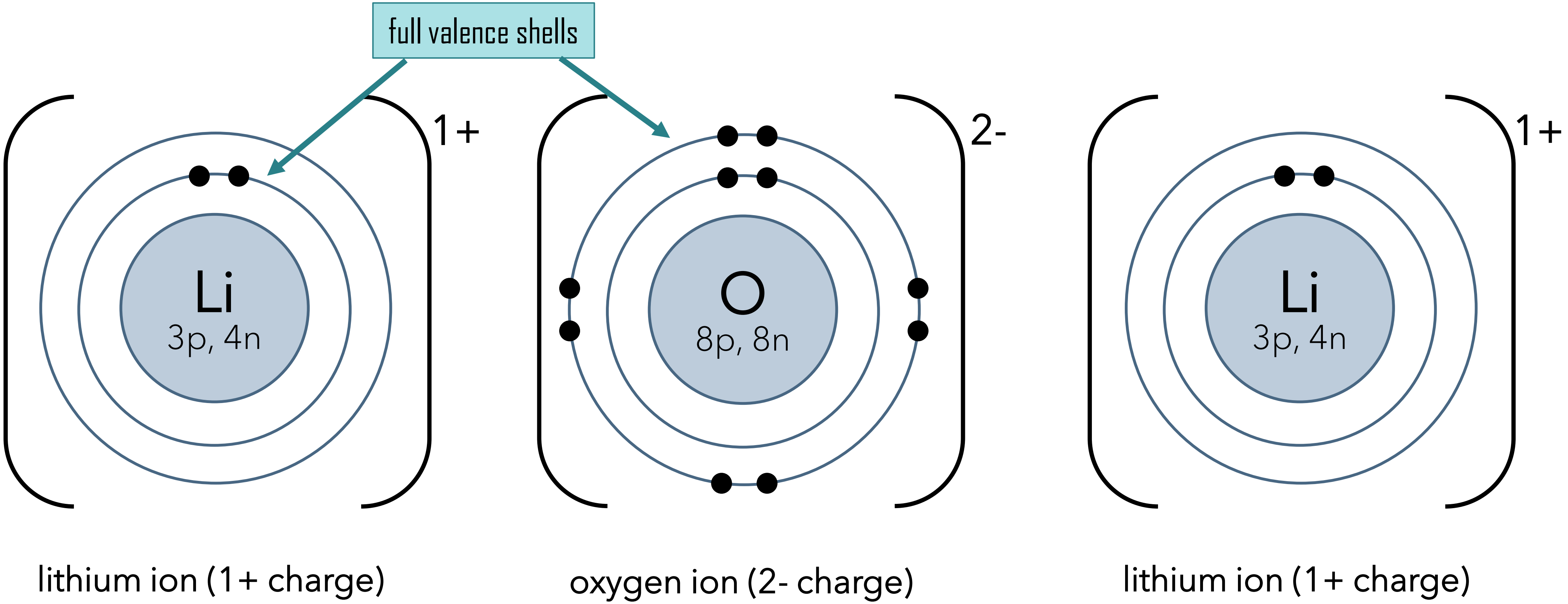


lithium atom (neutral)

oxygen atom (neutral)

lithium atom (neutral)

Ionic Compound Formation (Li_2O)



This ionic compound is **Li_2O** (lithium oxide). It has two Li^+ ions and one O^{2-} ion.

Bohr Models of Compounds

(textbook pgs ~120-124)

Bohr Models of Ionic Compounds

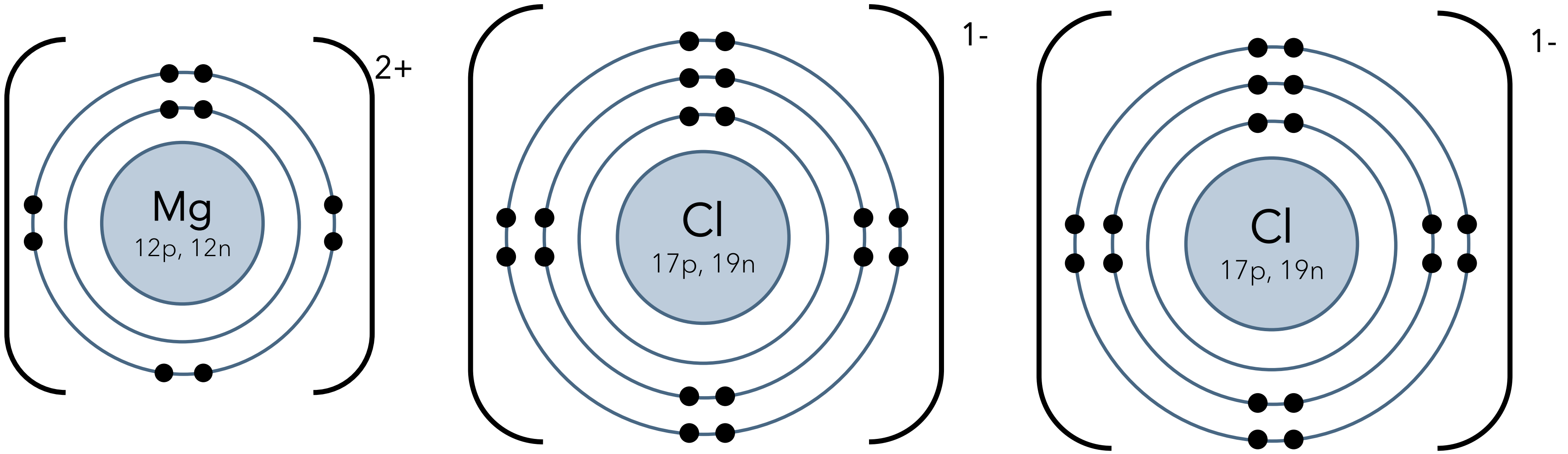
1. Determine how many of each ion is in the compound, from the subscripts.
2. Use the periodic table to find the ionic charge of each ion.
3. Draw the Bohr models of all the ions in the compound. (They should all have full valence shells.)

Practice:

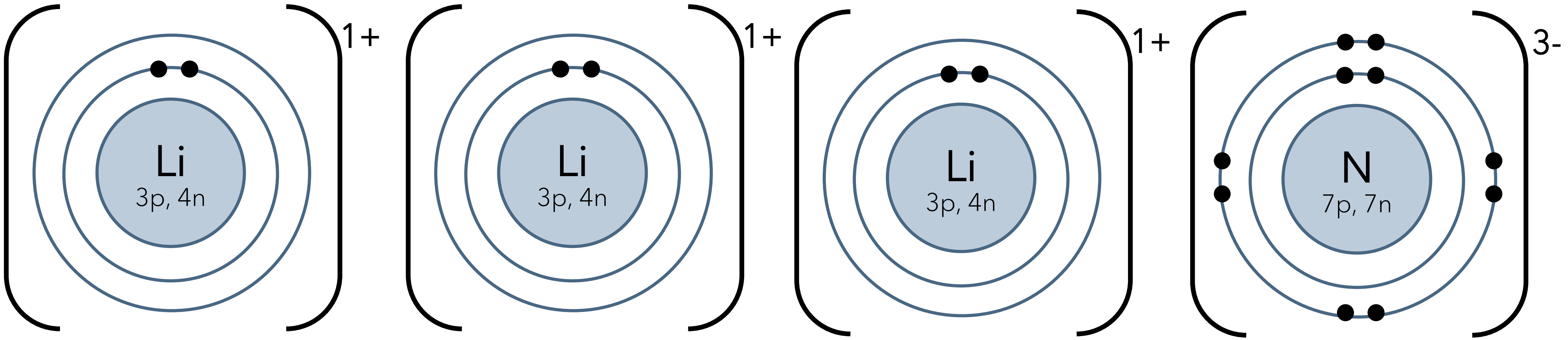
a) $MgCl_2$
b) Li_3N

Bohr Models of Ionic Compounds

$MgCl_2$



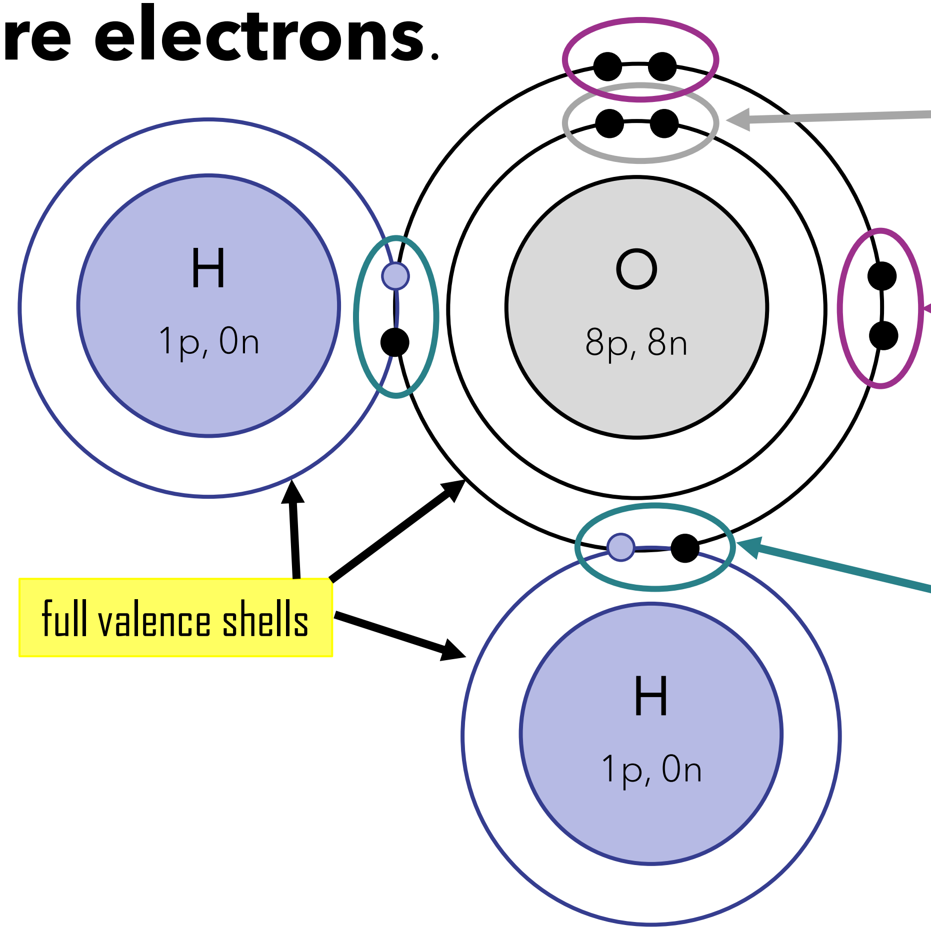
Li_3N



Covalent Compound Formation

- Covalent compounds form when two (or more) **non-metal atoms share electrons**.

This covalent compound is H_2O (water or dihydrogen monoxide). It has two hydrogen atoms and one oxygen atom.



(These electrons are not in the valence shell. This is *not* a lone pair.)

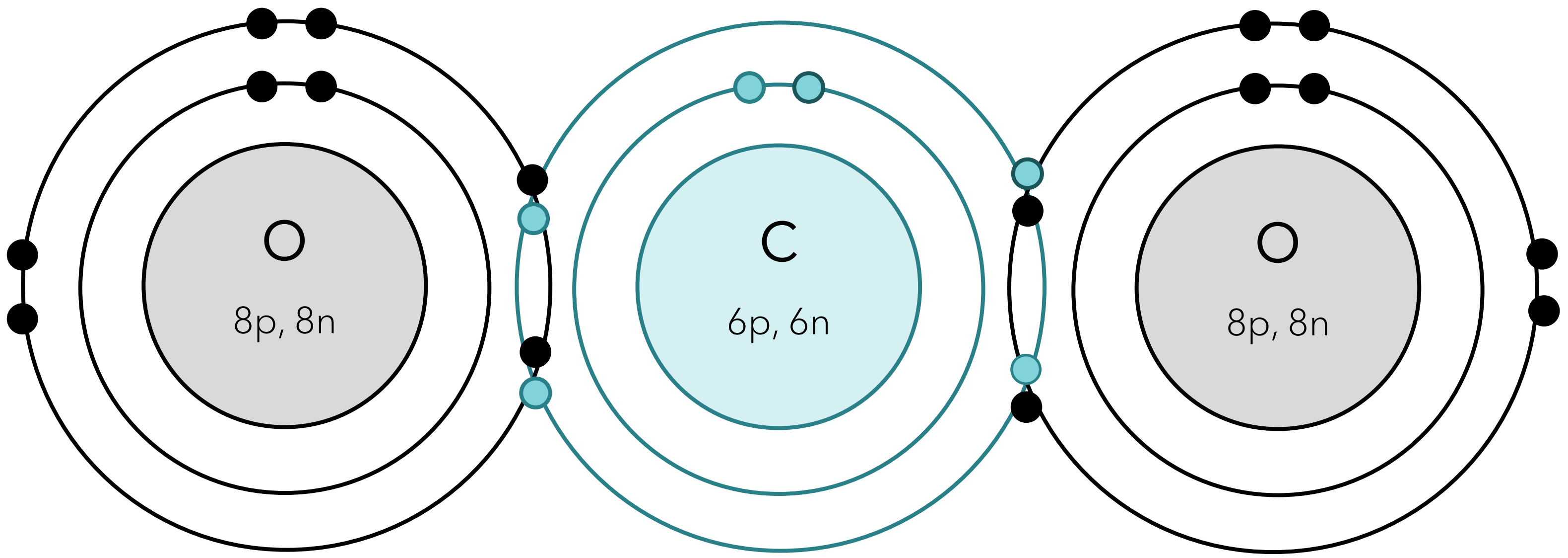
Lone pair: pair of **valence electrons** that is **not shared** between atoms

Bonding pair: **shared pair of valence electrons** in a covalent compound

Total: 2 bonding pairs, 2 lone pairs

Covalent Compound Formation

- Covalent compounds form when two (or more) **non-metal** atoms **share electrons**.



This covalent compound is CO_2 (carbon dioxide).
It has one carbon atom and two oxygen atoms.

Total: 4 bonding pairs, 4 lone pairs

Bohr Models of Covalent Compounds

1. Determine how many of each atom is in the compound, from the subscripts.
2. Draw the Bohr models of the atoms. 'Guess and check' what covalent bonds between valence electrons will cause all atoms to have a full valence shell.
3. Redraw the Bohr model, showing the covalent bonds.

Practice:

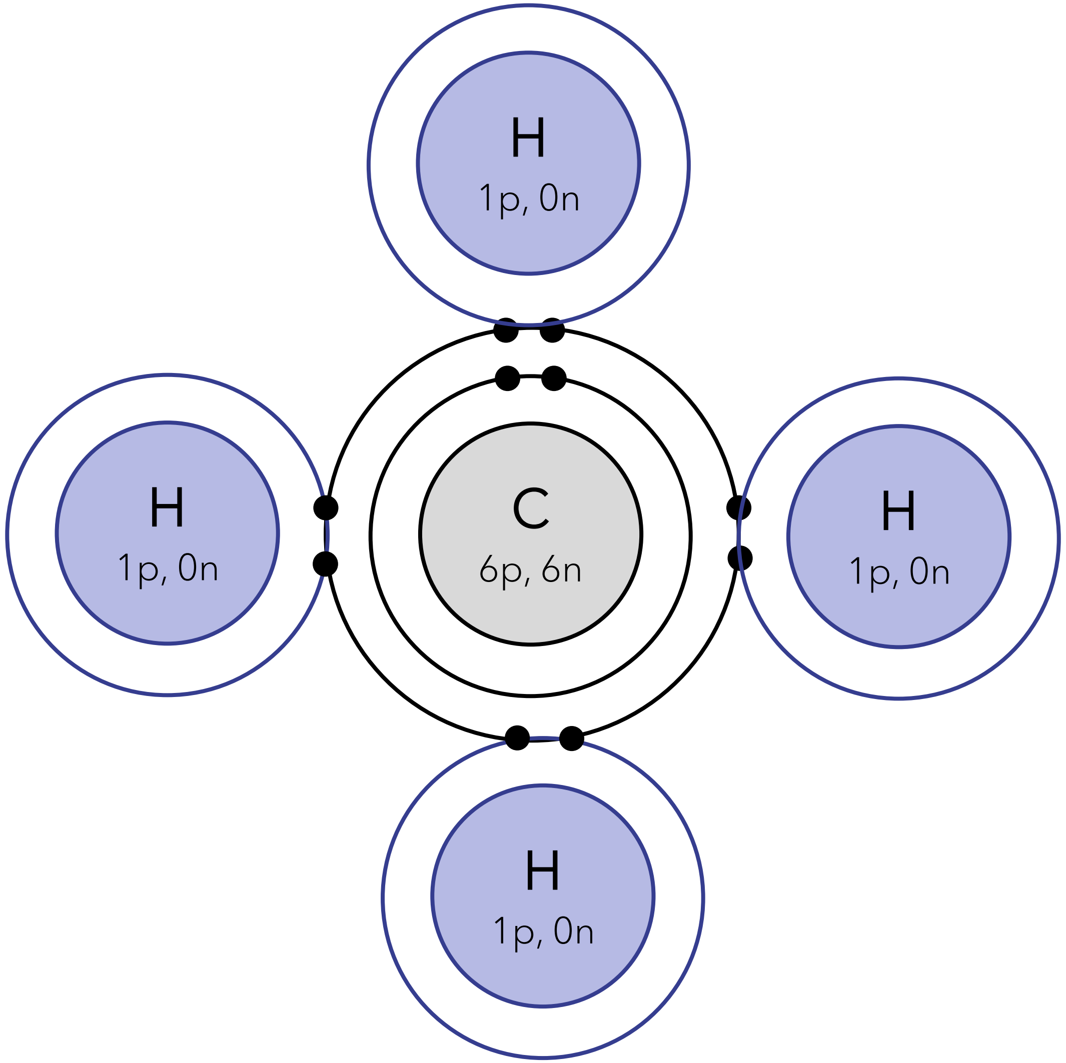
a) CH_4

b) N_2

Bohr Models of Covalent Compounds

Practice:

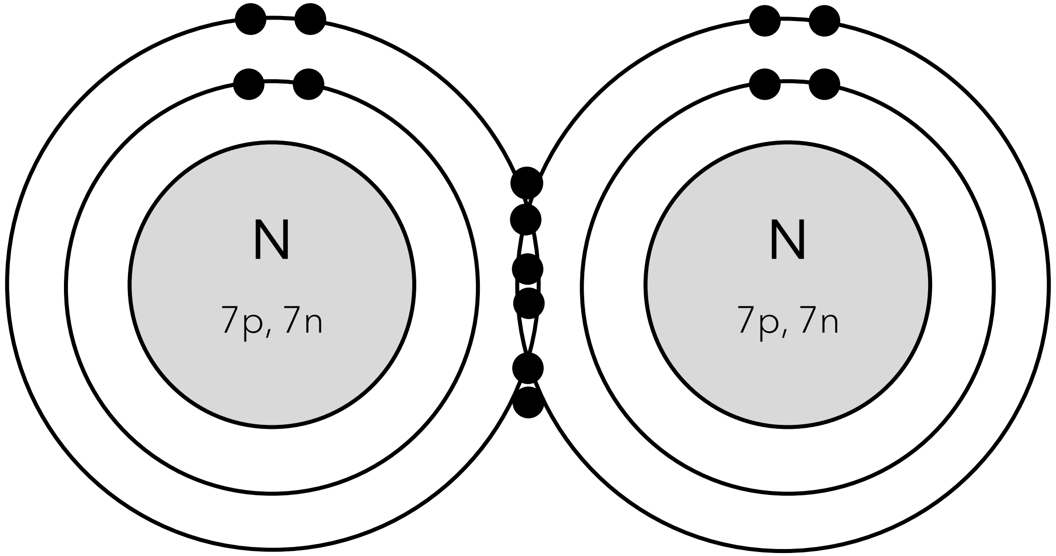
a) CH_4



Bohr Models of Covalent Compounds

Practice:

b) N_2

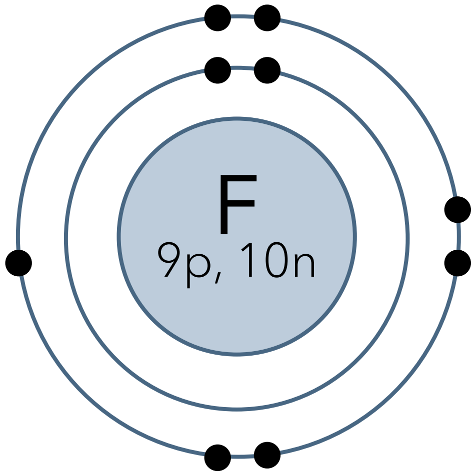


c) CO_2H_4 ???

Introducing Lewis Structures

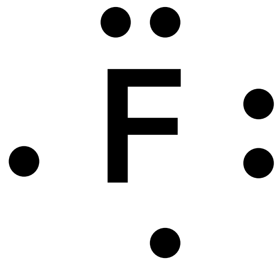
Bohr Model

- All electrons
- All energy shells
- Shows protons and neutrons
- Shows a lot of information, but is clunky and time-consuming

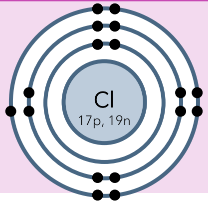
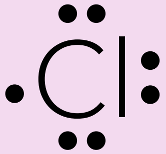
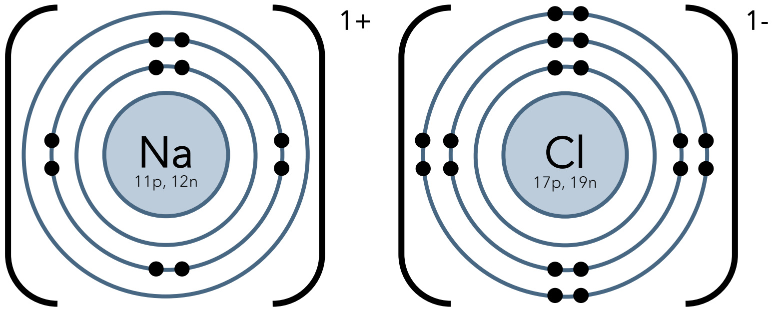
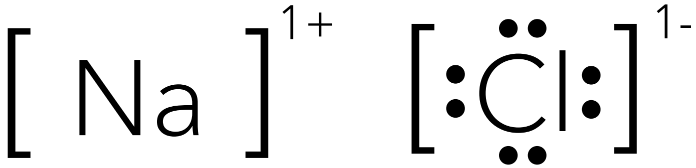
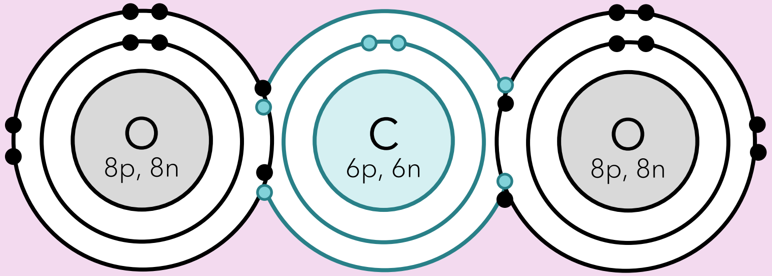
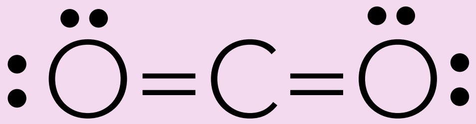


Lewis Structure

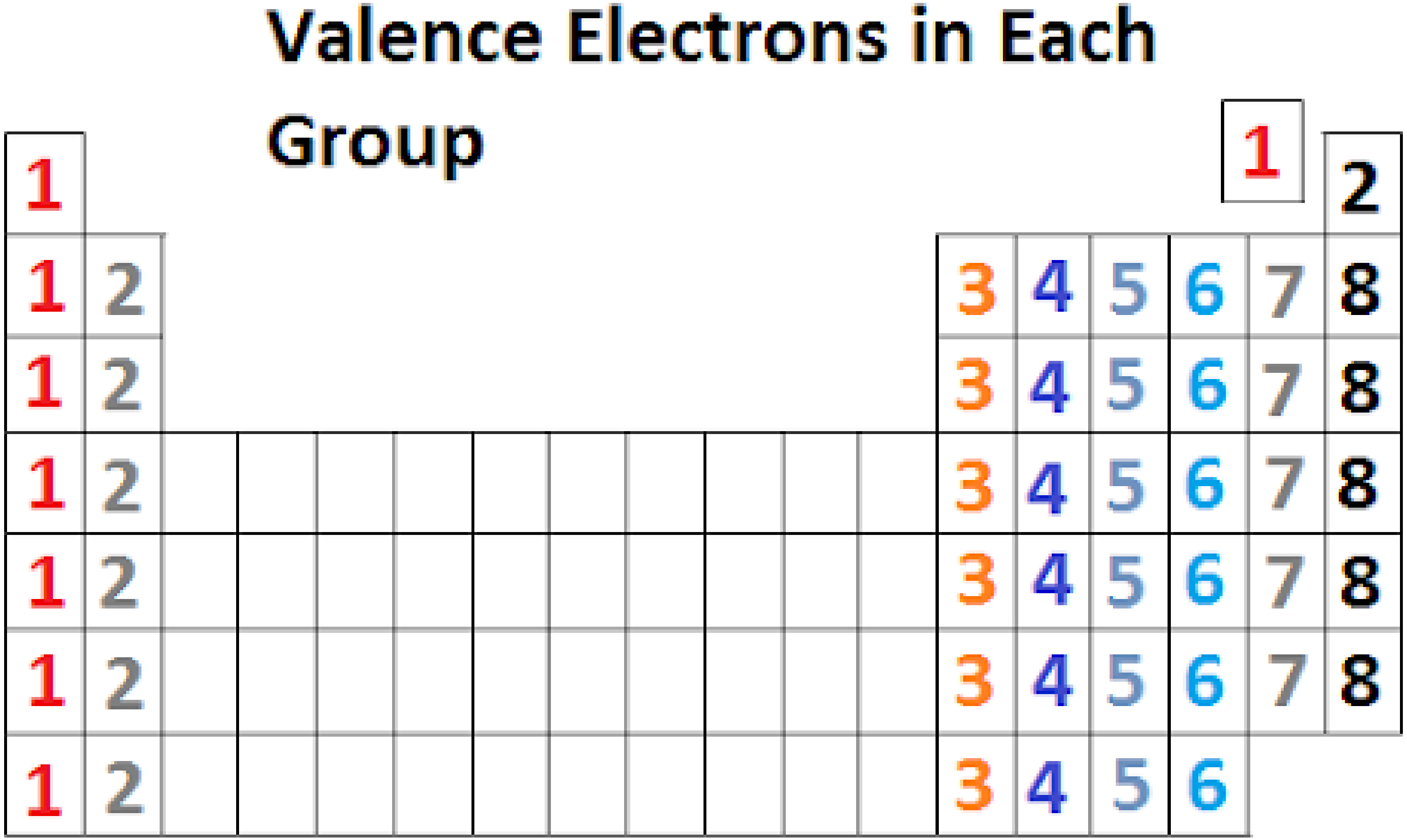
- Only **valence** electrons (except cations)
- Outermost shell only
- Protons and neutrons ignored
- Good at determining bonding in a **covalent** compound



Introducing Lewis Structures

	Bohr Model	Lewis Structure
Atom		
Ionic Compound		
Covalent Compound		

Lewis Structures of Atoms



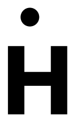
Look at the last digit of the group #. Exception: hydrogen and helium.

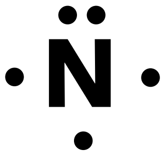
Lewis Structures of Atoms

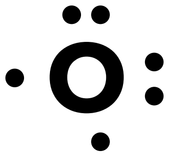
1. Write element symbol (capitalization matters!)
2. Draw valence electrons around, using the same positions as the Bohr model (i.e. clockwise, unpaired at first then paired)

Practice: Draw the Lewis structures of:

a) Mg atom 

c) H atom 

b) N atom 

d) O atom 

Lewis Structures of Ions and Ionic Compounds

Cation:

- Element symbol
- No electrons
- Square brackets and charge

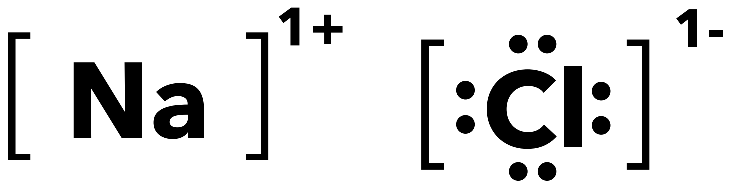
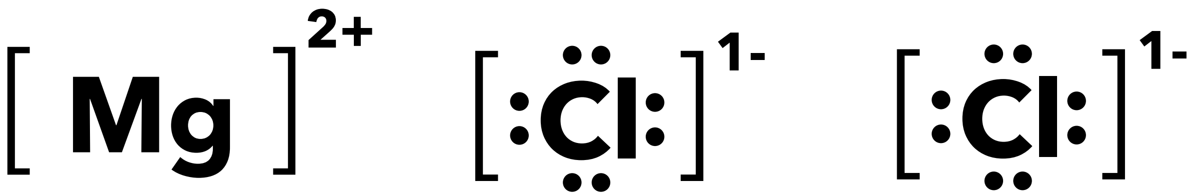
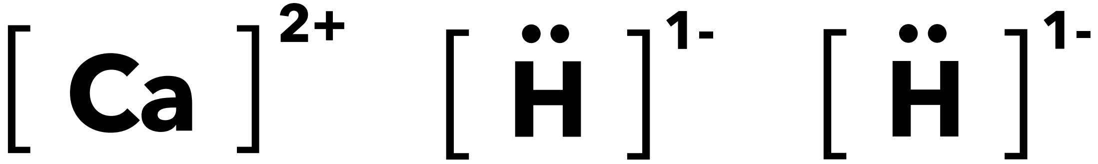
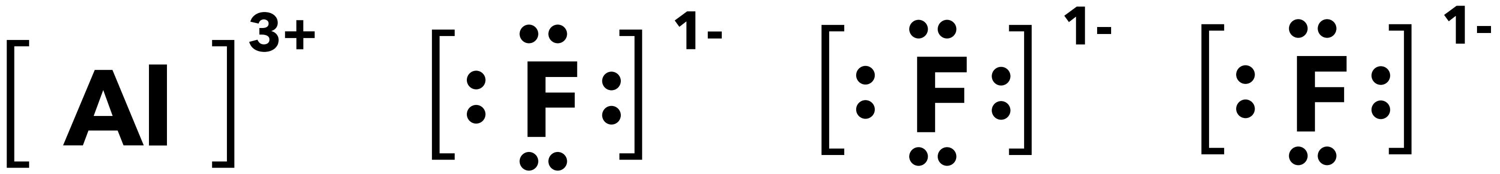
$[\mathrm{Mg}]^{2+}$

$[\mathrm{Na}]^{1+}$

Anion:

- Element symbol
- Full valence shell
- Square brackets and charge

Lewis Structures of Ions and Ionic Compounds

Practice. Draw the Lewis structures for the following:	
a) NaCl	
b) $MgCl_2$	
c) CaH_2	
d) AlF_3	

Lewis Structures of Covalent Compounds

Rule 1: All **valence electrons must be used.**

Rule 2: All atoms must have a **full valence shell.**

1. Draw the Lewis structure of each atom.
2. Determine how many bonds each atom “needs” to complete its valence shell.
3. Guess and check with single, double, and triple bonds until your structure satisfies Rule 1 AND Rule 2.

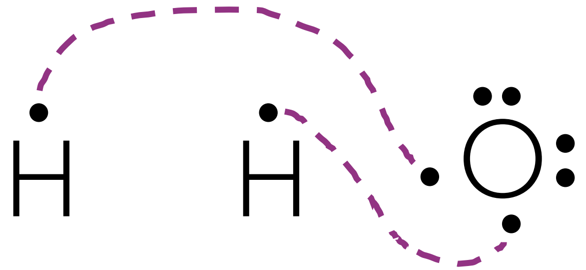
Lewis Structures of Covalent Compounds

Rule 1: All **valence electrons must be used.**

Rule 2: All atoms must have a **full valence shell.**

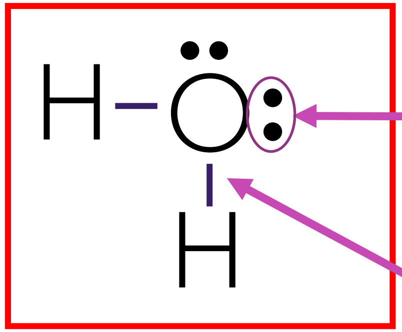
Example: H_2O

1. Draw the Lewis structure of each atom. (Count how many electrons you have in total; write this down.)
2. Determine how many bonds each atom "needs" to complete its valence shell.
3. Guess and check with single, double, and triple bonds until your structure satisfies Rule 1 AND Rule 2.



Each H needs 1 bond; O needs 2 bonds.

Total e = 8



This is a lone pair.

This is a single bond. It represents a bonding pair of electrons.

2 lone pairs;
2 bonding pairs

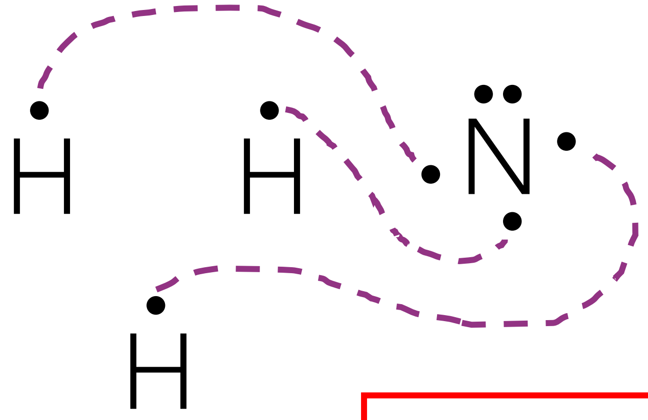
Lewis Structures of Covalent Compounds

Rule 1: All **valence electrons must be used.**

Rule 2: All atoms must have a **full valence shell.**

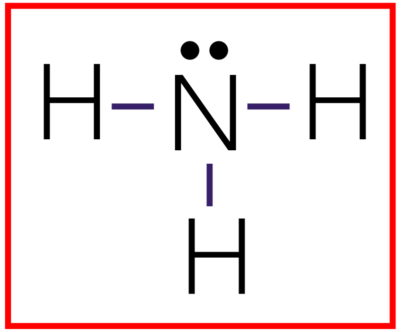
Example: NH_3

1. Draw the Lewis structure of each atom. (Count how many electrons you have in total; write this down.)
2. Determine how many bonds each atom "needs" to complete its valence shell.
3. Guess and check with single, double, and triple bonds until your structure satisfies Rule 1 AND Rule 2.



Each H needs 1 bond; N needs 3 bonds.

Total e = 8



1 lone pair;
3 bonding pairs

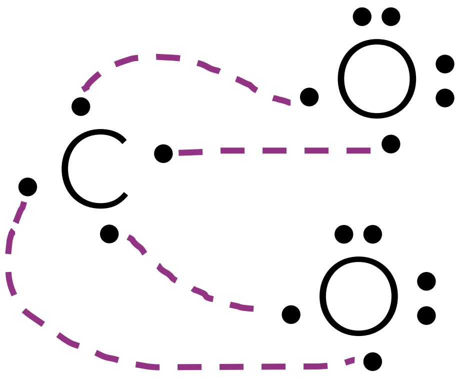
Lewis Structures of Covalent Compounds

Rule 1: All **valence electrons must be used.**

Rule 2: All atoms must have a **full valence shell.**

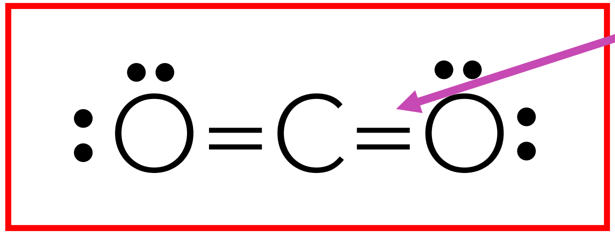
Example: CO_2

1. Draw the Lewis structure of each atom. (Count how many electrons you have in total; write this down.)
2. Determine how many bonds each atom "needs" to complete its valence shell.
3. Guess and check with single, double, and triple bonds until your structure satisfies Rule 1 AND Rule 2.



C needs 4 bonds; each O needs 2 bonds.

Total e = 16



This is a double bond. It represents two bonding pairs of electrons.

4 lone pairs;
4 bonding pairs

Lewis Structures of Covalent Compounds

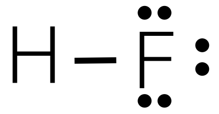
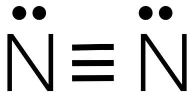
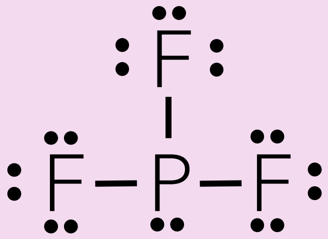
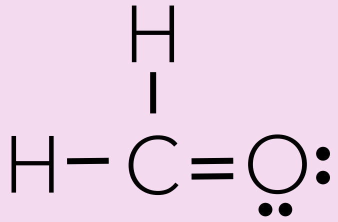
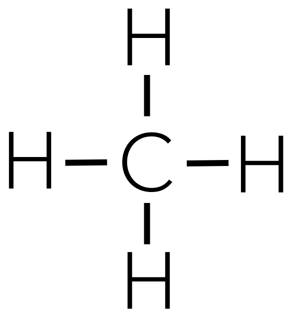
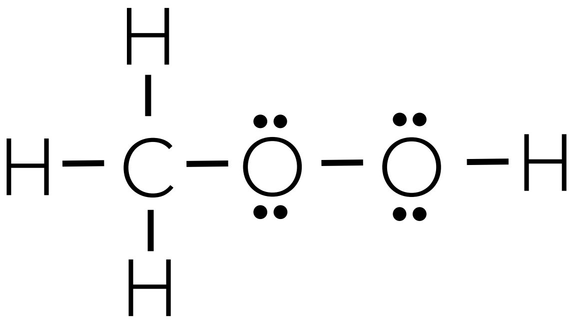
Try drawing the following covalent compounds!

- HF
- PF_3
- CH_4
- N_2 *
- CH_2O
- CO_2H_4 *(challenge)*

*Technically, N_2 is not a compound because it is only made of one element. But, the bonds between the atoms are covalent so we can still draw its Lewis structure.

Lewis Structures of Covalent Compounds

Try drawing the following covalent compounds!

	HF (3 lone pairs; 1 bonding pair)		N_2 * (2 lone pairs; 3 bonding pairs)
	PF_3 (10 lone pairs; 3 bonding pairs)		CH_2O (2 lone pairs; 4 bonding pairs)
	CH_4 (0 lone pairs; 4 bonding pairs)		CO_2H_4 (challenge) (4 lone pairs; 6 bonding pairs)

*Technically, N_2 is not a compound because it is only made of one element. But, the bonds between the atoms are covalent so we can still draw its Lewis structure.