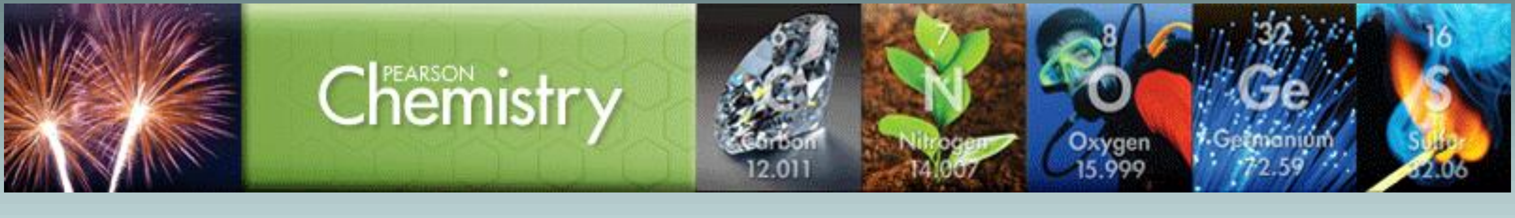
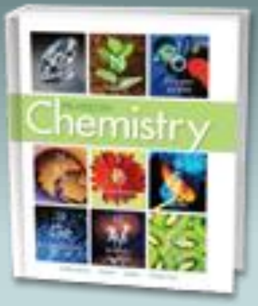




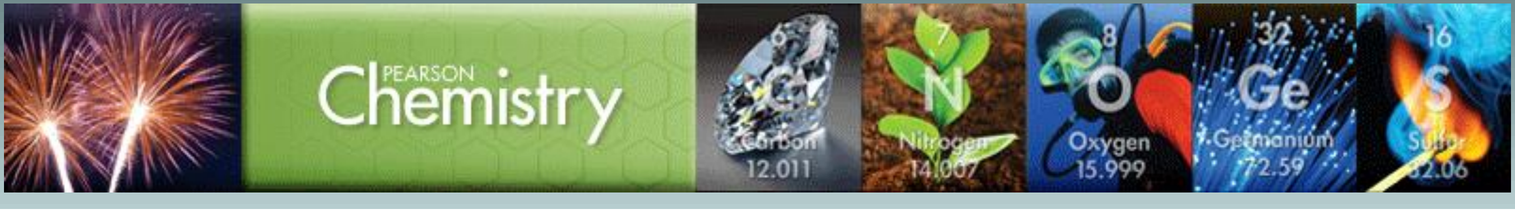
Chapter 9

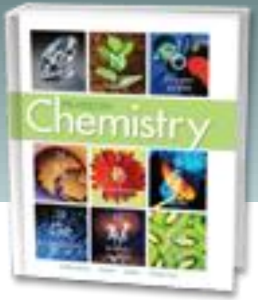
Chemical Names and Formulas

Naming and Writing Formulas for

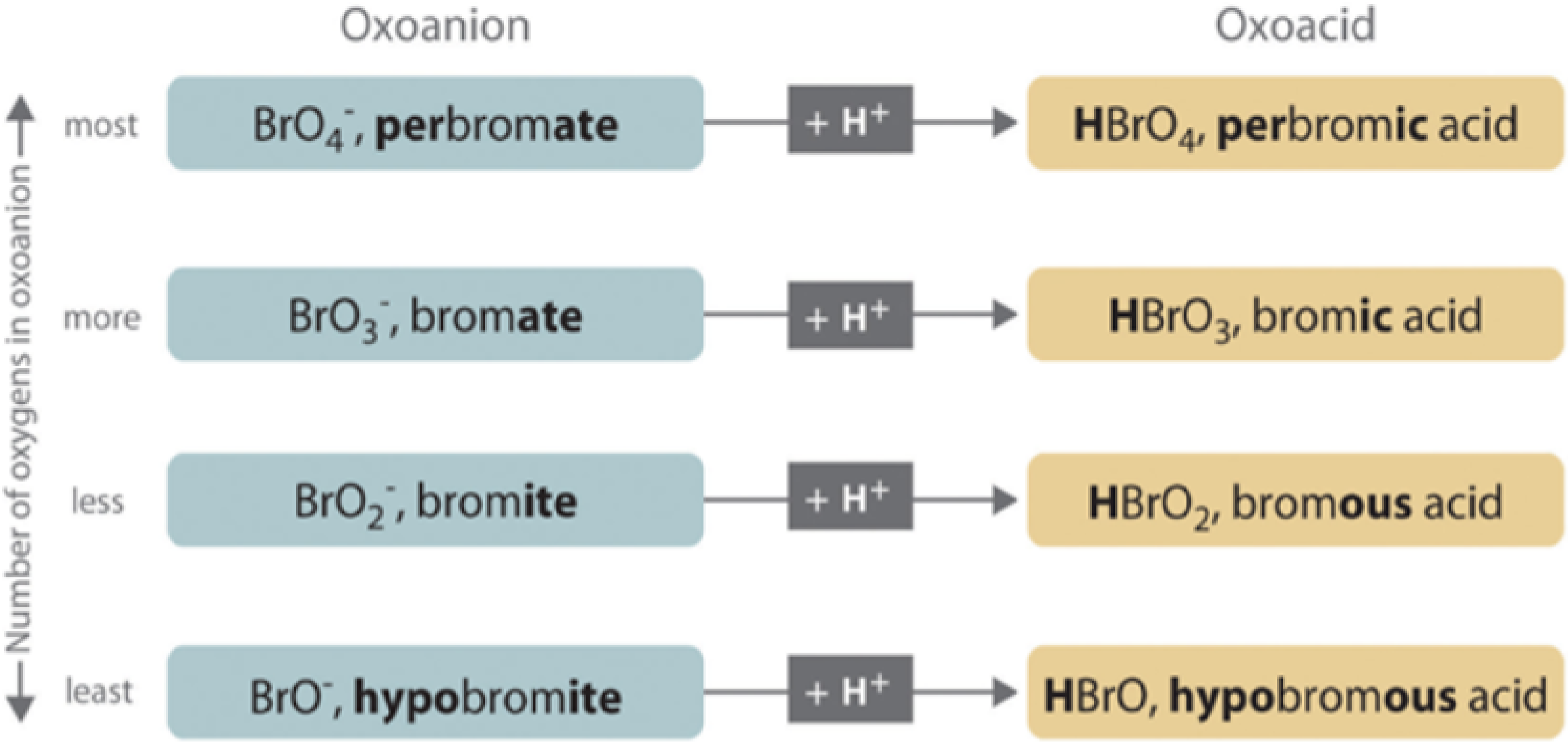
- Ionic Compounds
- Covalent Molecules
- Acids and Bases

Law of Definite Proportions
Law of Multiple Proportions





FORMULAS CHAPTER 9B



Number of oxygens in oxoanion	Oxoanion		Oxoacid
most	BrO_4^-, **per**brom**ate**	+ H^+ →	**H**BrO_4, **per**brom**ic** acid
more	BrO_3^-, brom**ate**	+ H^+ →	**H**BrO_3, brom**ic** acid
less	BrO_2^-, brom**ite**	+ H^+ →	**H**BrO_2, brom**ous** acid
least	BrO^-, **hypo**brom**ite**	+ H^+ →	**H**BrO, **hypo**brom**ous** acid

Topics:

1. Chemical Names and Formulas

Objectives:

1. Explain how to determine the charges of monatomic ions.
2. Apply the rules for naming and writing formulas for compounds with polyatomic ions.
3. Determine the names and formulas of ionic and covalent compounds, of acids and bases.
4. Understand Law of Definite Proportions

WARM-UP

Naming and Making Chemical Formulas

If the formula is provided, name the compound or molecule.

If the formula name is provided, make the formula. (add a second name if appropriate)

Potassium nitride	
Potassium chromate	
	Fe_2S_3
	$Ba(C_2H_3O_2)_2$
	$Zn_3(PO_4)_2$
	$NaBr$
	$Cu(ClO_3)$
Nitrogen dioxide	
	Hg_2Br_2
Hydrogen peroxide	
Potassium hydroxide	
	PF_3

Naming and Making Chemical Formulas

If the formula is provided, name the compound or molecule.

Potassium nitride	$K^{+1}_{3}N^{-3}$
Potassium chromate	$K^{+1}_{2}(CrO_{4})^{-2}$
Ferric sulfide, Iron(III) sulfide, di-iron Trisulfide	$Fe^{+3}_{2}S^{-2}_{3}$
Barium acetate	$Ba^{+2}(C_{2}H_{3}O_{2})^{-1}_{2}$
Zinc phosphate	$Zn^{+1}_{3}(PO_{4})^{-3}_{2}$
Sodium bromide	$Na^{+1}Br^{-1}$
Cuprous chlorate, Copper(I) chlorate, monocopper monochlorate	$Cu^{+1}(ClO_{3})^{-1}$
Nitrogen dioxide, Nitrogen(IV) oxide	$N^{+4}O^{-2}_{2}$
Mercury(I) bromide, Mercurous bromide, dimercury dibromide	$Hg^{+1}_{2}Br^{-1}_{2}$
Hydrogen peroxide, dihydrogen dioxide	$H^{+1}_{2}O^{-1}_{2}$
Potassium hydroxide	$K^{+1}(OH)^{-1}$
Phosphorus TriFluoride	$P^{+3}F^{-1}_{3}$

What Is the Method for Naming Acids & Bases?

Acids and Bases (overview of theory)

Acids:

- Increase concentration of H^+ ions in aqueous (water) solution.
- May be ionic or covalent.
- Generally contain H atoms bonded to other atoms or to polyatomic ions.

Properties:

- Turn blue litmus paper red.
- Taste sour.

Bases:

- Increase concentration of $(OH)^-$ ions in aqueous solution.
- Ionic bases contain OH^- in formula.

Properties:

- Turn red litmus paper blue.
- Feel slippery or soapy.

STRATEGY

Naming Binary Acids

The simplest acids contain Hydrogen and we call these **binary** acids (example: HCl) which contains only 2 elements.

- Acids donate an H+ ion in solution.

For Naming, use → “hydro _____ ic acid"

- Start with *hydro-* to indicate H
- Add the root of the nonmetal
- Add *-ic*

TRY IT

Formula	Solid or Dry gas	Aqueous
HCl		
HBr		
HF		
H_2S		

Naming Binary Acids

The simplest acids contain Hydrogen and we call these **binary** acids (example: HCl) which contains only 2 elements

- Acids donate an H+ ion in solution

For Naming, use → "hydro ______ ic" acid (aq)

TRY IT

- Start with *hydro-* to indicate H
- Add the root of the nonmetal
- Add *-ic*

Remember "hydrogen" in an acid does not follow the covalent molecule naming rules.

Formula	Solid or Dry gas	Aqueous
HCl	Hydrogen Chloride	Hydrochloric acid HCl aq
HBr	Hydrogen Bromide	Hydrobromic acid HBr aq
HF	Hydrogen Fluoride	Hydrofluoric acid HF aq
H_2S	Hydrogen Sulfide	Hydrosulfuric acid H_2S aq

Naming Common Acids **(non-binary)**

Name	Name (anhydrous)	Formula
Sulfuric acid	Hydrogen Sulfate	H_2SO_4
Nitric acid	Hydrogen Nitrate	HNO_3
Acetic acid (Vinegar)	Hydrogen Acetate	$HC_2H_3O_2$
Phosphoric acid	Hydrogen Phosphate	H_3PO_4
Carbonic acid	Hydrogen Carbonate	H_2CO_3

Many industrial processes, including steel and fertilizer manufacturing, use acids. Also, food and drink.

Naming Acids Containing Oxygen

STRATEGY

These molecules end in "-ate" or "-ite"

Molecules are named based on the number of oxygens in the molecule

Naming "oxyacids" when placed in water

- The "**-ate**" is changed to "**-ic**" OR
- the "**-ite**" is changed to "**-ous**"

	Solid	aqueous	In Water
H_2SO_4	Hydrogen Sulfate	$H_2SO_{4\,(aq)}$	
H_2SO_3	Hydrogen Sulfite	$H_2SO_{3\,(aq)}$	

Naming Acids Containing Oxygen

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Molecules are named based on the number of oxygens in the molecule

Naming "oxyacids" when placed in water

- The "**-ate**" is changed to "**-ic**" OR
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	Solid	aqueous	In Water
H_2SO_4	Hydrogen Sulfate	$H_2SO_{4\,(aq)}$	Sulfur**ic** Acid
H_2SO_3	Hydrogen Sulfite	$H_2SO_{3\,(aq)}$	Sulfur**ous** Acid

STRATEGY

Sulfate Series

Dry or Gaseous State	Name	**Aqueous** State	Acid Name
H_2SO_5		$H_2SO_{5\ (aq)}$	
H_2SO_4		$H_2SO_{4\ (aq)}$	
H_2SO_3		$H_2SO_{3\ (aq)}$	
H_2SO_2		$H_2SO_{2\ (aq)}$	

Use the "–ate" acid as the standard of comparison for the number of oxygen atoms. E.g. Hydrogen Sulfate becomes Sulfuric Acid.

- One more oxygen atom changes the name to "per" (above)
- One less oxygen atom changes the name to "-ite"
- Two less oxygen atoms changes the name to "hypo" (under) … "ite"

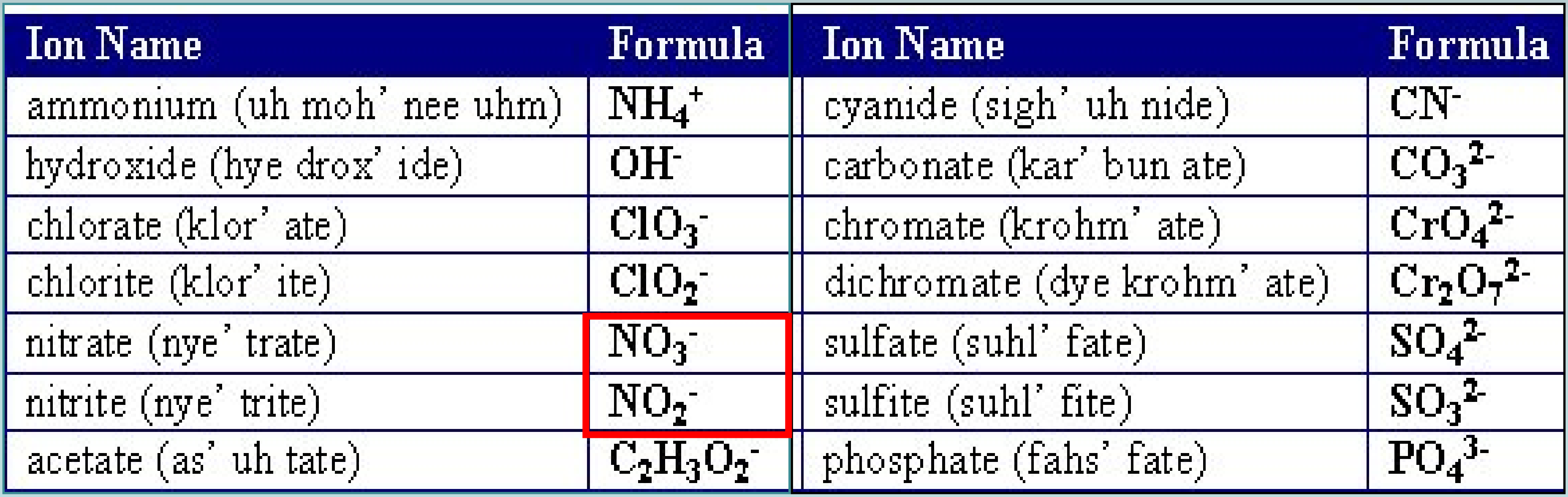
Sulfate Series

Dry or Gaseous State	Name	**Aqueous** State	Acid Name
H_2SO_5	Hydrogen perSulfate	$H_2SO_{5\ (aq)}$	Per Sulfuric Acid
H_2SO_4	Hydrogen Sulfate	$H_2SO_{4\ (aq)}$	Sulfuric Acid
H_2SO_3	Hydrogen Sulfite	$H_2SO_{3\ (aq)}$	Sulfurous Acid
H_2SO_2	Hydrogen hypoSulfite	$H_2SO_{2\ (aq)}$	Hyposulfurous Acid

Use the "–ate" acid as the standard of comparison for the number of oxygen atoms. E.g. Hydrogen Sulfate becomes Sulfuric Acid.

- One more oxygen atom changes the name to "per" (above)
- One less oxygen atom changes the name to "-ite"
- Two less oxygen atoms changes the name to "hypo" (under) … "ite"

This convention works with any oxygen containing acids.



Ion Name	Formula	Ion Name	Formula
ammonium (uh moh' nee uhm)	NH_4^+	cyanide (sigh' uh nide)	CN^-
hydroxide (hye drox' ide)	OH^-	carbonate (kar' bun ate)	CO_3^{2-}
chlorate (klor' ate)	ClO_3^-	chromate (krohm' ate)	CrO_4^{2-}
chlorite (klor' ite)	ClO_2^-	dichromate (dye krohm' ate)	$Cr_2O_7^{2-}$
nitrate (nye' trate)	NO_3^-	sulfate (suhl' fate)	SO_4^{2-}
nitrite (nye' trite)	NO_2^-	sulfite (suhl' fite)	SO_3^{2-}
acetate (as' uh tate)	$C_2H_3O_2^-$	phosphate (fahs' fate)	PO_4^{3-}

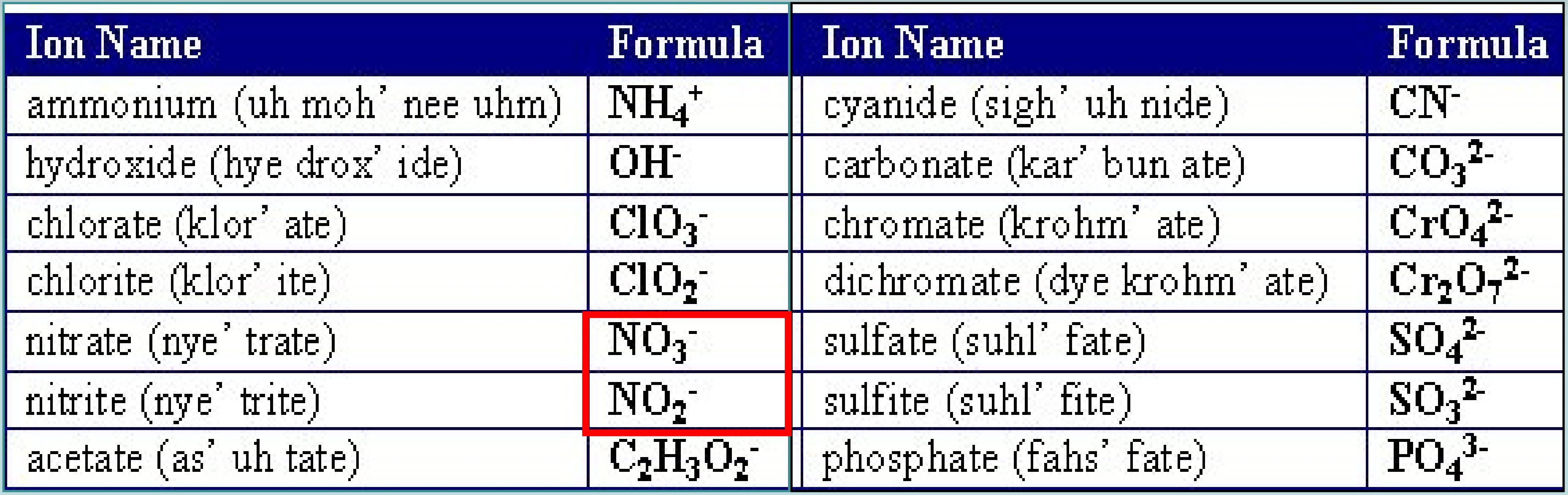
NO^-
NO_2^-
NO_3^- Nitrate
NO_4^-

Addition of another O

In water

*The "**-ate**" is changed to "**-ic**"* OR
*the "**-ite**" is changed to "**-ous**"*

This convention works with any oxygen containing acids.



Ion Name	Formula	Ion Name	Formula
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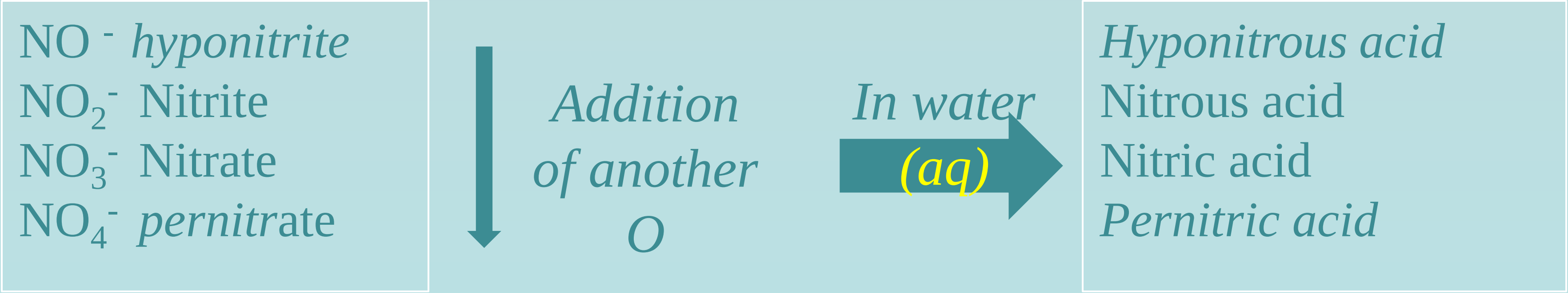
hydroxide (hye drox' ide)	OH^-	carbonate (kar' bun ate)	CO_3^{2-}
chlorate (klor' ate)	ClO_3^-	chromate (krohm' ate)	CrO_4^{2-}
chlorite (klor' ite)	ClO_2^-	dichromate (dye krohm' ate)	$Cr_2O_7^{2-}$
nitrate (nye' trate)	NO_3^-	sulfate (suhl' fate)	SO_4^{2-}
nitrite (nye' trite)	NO_2^-	sulfite (suhl' fite)	SO_3^{2-}
acetate (as' uh tate)	$C_2H_3O_2^-$	phosphate (fahs' fate)	PO_4^{3-}



NO^- *hyponitrite*
NO_2^- Nitrite
NO_3^- Nitrate
NO_4^- *pernitrate*

Addition of another O

In water
(aq)

Hyponitrous acid
Nitrous acid
Nitric acid
Pernitric acid

*The “**-ate**” is changed to “**-ic**” OR*
*the “**-ite**” is changed to “**-ous**”*

QUICK CHECK

Chlorate Series

Dry or Gaseous State	Name	Aqueous State	Name
$HClO_4$		$HClO_{4\,(aq)}$	
$HClO_3$		$HClO_{3\,(aq)}$	
$HClO_2$		$HClO_{2\,(aq)}$	
$HClO$		$HClO_{(aq)}$	

Phosphate Series

Dry or Gaseous State	Name	Aqueous State	Name
H_3PO_5		$H_3PO_{5\,(aq)}$	
H_3PO_4		$H_3PO_{4\,(aq)}$	
H_3PO_3		$H_3PO_{3\,(aq)}$	
H_3PO_2		$H_3PO_{2\,(aq)}$	

QUICK CHECK

Chlorate Series

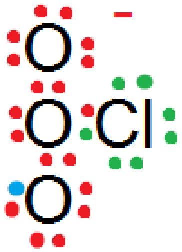
Dry or Gaseous State	Name	**Aqueous** State	Name
$HClO_4$	Hydrogen perchlorate	$HClO_{4\,(aq)}$	Perchloric Acid
$HClO_3$	Hydrogen Chlorate	$HClO_{3\,(aq)}$	Chloric Acid
$HClO_2$	Hydrogen Chlorite	$HClO_{2\,(aq)}$	Chlorous Acid
$HClO$	Hydrogen hypoChlorite	$HClO_{(aq)}$	HypoChlorous Acid

Phosphate Series

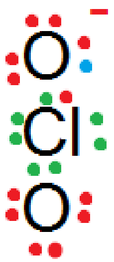
Dry or Gaseous State	Name	**Aqueous** State	Name
H_3PO_5	Hydrogen Perphosphate	$H_3PO_{5\,(aq)}$	Perphosphoric Acid
H_3PO_4	Hydrogen Phosphate	$H_3PO_{4\,(aq)}$	Phosphoric Acid
H_3PO_3	Hydrogen Phosphite	$H_3PO_{3\,(aq)}$	Phosphorous Acid
H_3PO_2	Hydrogen hypoPhosphite	$H_3PO_{2\,(aq)}$	HypoPhosphorous Acid

Polyatomic Ion Lewis Structures

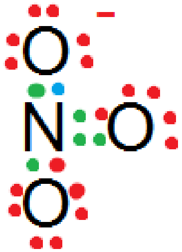
All of these polyatomic ions can form acid in water.



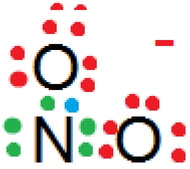
Chlorate



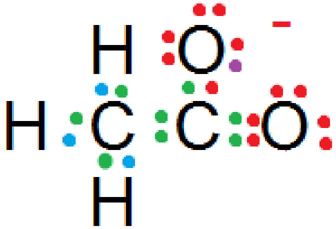
Chlorite



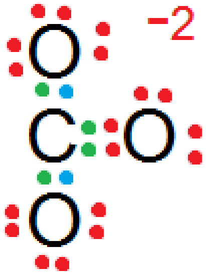
Nitrate



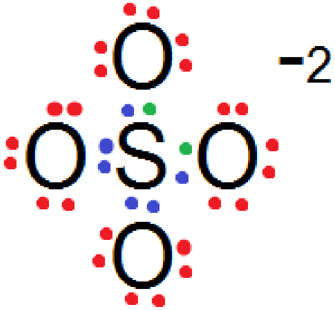
Nitrite



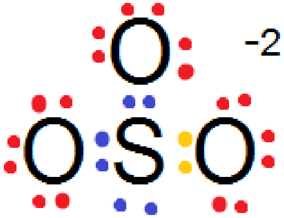
Acetate



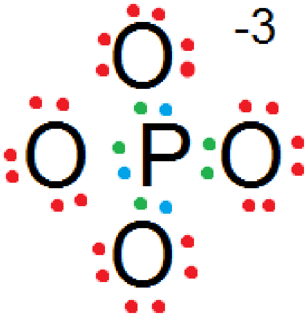
Carbonate



Sulfate



Sulfite



Phosphate

Name the Acid or Give its Formula

QUICK CHECK

$HNO_{2\ (aq)}$

$HI_{\ (aq)}$

$HClO_{4\ (aq)}$

$HClO_{\ (aq)}$

$HCN_{\ (aq)}$ (cyanide)

Carbonic acid in carbonated beverages

Hydrofluoric acid

Phosphoric acid in soft drinks, teeth whitener, preserving foods

Name the Acid or Give its Formula

QUICK CHECK

$HNO_{2\,(aq)}$

nitrous acid

$HI_{(aq)}$

hydroiodic acid

$HClO_{4\,(aq)}$

perchloric acid

$HClO_{(aq)}$

hypochlorous acid

$HCN_{(aq)}$ (cyanide)

hydrocyanic acid (treated as binary)

Carbonic acid in carbonated beverages

$H_2CO_{3\,(aq)}$

Hydrofluoric acid

$HF_{(aq)}$

Phosphoric acid in soft drinks, teeth whitener, preserving foods

$H_3PO_{4\,(aq)}$

Naming Bases

Simple **bases** are ionic compounds which produce hydroxide ions $(OH)^-$ when dissolved in water (aq).

Bases are named in the same way as other ionic compounds → the name of the cation is followed by the name of the anion.

Sodium hydroxide (NaOH) dissociates into sodium cations (Na^+) and hydroxide anions $(OH)^-$.

Formula	**Base Name**
NaOH aq	
KOH aq	
$Ca(OH)_2$ aq	

Naming Bases

Simple **bases** are ionic compounds which produce hydroxide ions $(OH)^-$ when dissolved in water.

Bases are named in the same way as other ionic compounds → the name of the cation is followed by the name of the anion.

Sodium hydroxide (NaOH) dissociates into sodium cations (Na^+) and hydroxide anions $(OH)^-$.

Formula	Base Name
NaOH aq	Sodium hydroxide
KOH aq	Potassium hydroxide
$Ca(OH)_2$ aq	Calcium hydroxide

Naming Bases

STRATEGY

To write the formula for a base:

- Write the symbol for the metal cation
- Then write the formula for the hydroxide ion.
- Then, balance the ionic charges just as you would for any ionic compound.

Write the formula and give the name for the base formed when Aluminum is dissolved in water:

Naming Bases

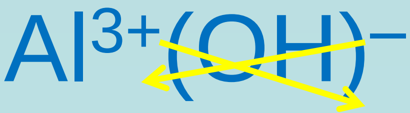
To write the formula for a base:

- Write the symbol for the metal cation
- Then write the formula for the hydroxide ion.
- Then, balance the ionic charges just as you would for any ionic compound.

Write the formula and give the name for the base formed when Aluminum is dissolved in water:

Aluminum cation (Al^{3+})

hydroxide anion $(OH)^{-}$



$Al^{3+}(OH)^{-}$

Aluminum hydroxide: $Al(OH)_{3\ (aq)}$

The Law of Definite Proportions

Proust’s discovery:

- Samples of a compound have the same ratio of elements.
- CopperII carbonate was composed of 1 part carbon, 4 parts oxygen, and 5 parts copper by weight.
- **Law of definite proportions**: pure reactants always combine in the same proportion to produce a given substance

The Law of Definite Proportions

TRY IT

CopperII carbonate was composed of 1 part carbon, 4 parts oxygen, and 5 parts copper by weight. Prove definite proportions.

The Law of Definite Proportions

TRY IT

- CopperII carbonate was composed of **1** part carbon, **4** parts oxygen, and **5** parts copper by weight:

$Cu^{+2}(CO_3)^{-2}$ total mass of 124 g/mol (see periodic table)

Cu (~64 g/mol)	Carbon (12 g/mol)	Oxygen 3(16) = 48 g/mol
64/124 = .5	12/124 = 0.1	48/124 = 0.4

0.1 : 0.4 : 0.5 = **1 : 4 : 5**

- **Law of definite proportions**: Copper, carbon, and oxygen will always combine in the same proportion to produce $Cu^{+2}(CO_3)^{-2}$.

The Law of Definite Proportions

Example Set Up:

Magnesium sulfide (MgS) is composed of magnesium cations and sulfide anions.

Use the periodic table and “molar” masses of the elements

Mg = ?

S = ?

The Mg:S ratio of these masses is ?

The Law of Definite Proportions

Example Set Up:

Magnesium sulfide (MgS) is composed of magnesium cations and sulfide anions.

Use the periodic table and “molar” masses of the elements

Mg = 24.3 g/mol

S = 32.1 g/mol

The Mg:S ratio of these masses is 24.3/32.1 or **0.757:1**; this ratio never changes.

The Law of Definite Proportions

Example:

Magnesium sulfide (MgS) is composed of magnesium cations and sulfide anions.

When a 100.00 g sample of magnesium sulfide is decomposed into its elements, 43.13 g of magnesium and 56.87 g of sulfur result.

The Mg:S ratio of these masses is **43.13 / 56.87** or 0.758 : 1; this ratio never changes.

Magnesium sulfide obeys the Law of Definite Proportions, which states that in samples of any chemical compound, the masses of the elements are always in the same proportions.

Law of Multiple Proportions (Dalton)

When one element combines with another to form more than one compound, the **mass ratios** of the elements in the compounds are simple whole numbers of each other.

Law of Definite Proportions compares S to O within EACH compound.

Sulfate series $\overbrace{SO}{}_4^{-2}$ … $\underbrace{SO_5^{-2},\ SO_4}\underbrace{{}^{-2},\ SO_3}\underbrace{{}^{-2},\ SO_2}{}^{-2}$

Law of Multiple Proportions compares the amount of "Oxygen" BETWEEN each compound.

Law of Multiple Proportions (Dalton)

When **one element** combines with another to form **more than one compound**, the **mass ratios** of the elements in the compounds are simple whole numbers of each other.

Phosphate series PO_4^{-3} … PO_5^{-3} , PO_4^{-3} , PO_3^{-3} , PO_2^{-3}

Chlorate series ClO_3^{-1} … ClO_4^{-1} , ClO_3^{-1} , ClO_2^{-1} , ClO^{-1}

Nitrate series NO_3^{-1} … NO_4^{-1} , NO_3^{-1} , NO_2^{-1} , NO^{-1}

Consider the ratio of “Oxygen” BETWEEN each compound.

Law of Multiple Proportions (Dalton)

When two elements combine to form more than one compound, the **masses** of one element which combines with a fixed mass of the other element are in a **ratio of small whole numbers**.

Two familiar compounds:

water, H_2O and hydrogen peroxide H_2O_2,

are formed from the same two elements.

Although these compounds are formed by the elements hydrogen and oxygen, they have different physical and chemical properties.

Law of Multiple Proportions (Dalton)

Two familiar compounds, water, H_2O, and hydrogen peroxide H_2O_2, are formed from the same two elements.

DEFINITE PROPORTIONS:

In hydrogen peroxide, H_2O_2, ____ g of oxygen are present for ____ g of hydrogen. The mass ratio of oxygen to hydrogen is always ____.

In water, H_2O, the mass ratio of oxygen to hydrogen is always ____ or ____.

MULTIPLE PROPORTIONS:

$$\frac{\underline{\quad}\text{ g O (in }H_2O_2\text{ sample that has 1 g H)}}{\underline{\quad}\text{ g O (in }H_2O\text{ sample that has 1 g H)}} = \frac{\qquad}{\qquad} = \frac{\qquad}{\qquad} = \underline{\qquad\quad}$$

Law of Multiple Proportions (Dalton)

Two familiar compounds, water, H_2O, and hydrogen peroxide H_2O_2, are formed from the same two elements.

DEFINITE PROPORTIONS:

In hydrogen peroxide, H_2O_2, 32.0 g of oxygen are present for 2.0 g of hydrogen. The mass ratio of oxygen to hydrogen is always 16:1.

In water, H_2O, the mass ratio of oxygen to hydrogen is always 16:2 or 8:1.

MULTIPLE PROPORTIONS:

$$\frac{16\text{ g O (in } H_2O_2 \text{ sample that has 1 g H)}}{8\text{ g O (in } H_2O \text{ sample that has 1 g H)}} = \frac{16}{8} = \frac{2}{1} = 2:1$$

Laws of Definite & Multiple Proportion Application

The small paper clip’s mass is 0.5 g, the large 1.5 g

Determine the Definite & Multiple Proportions:

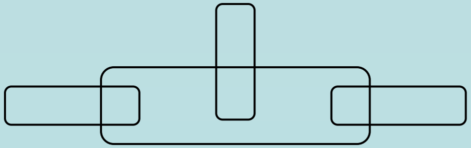
Definite Proportion

Multiple Proportion

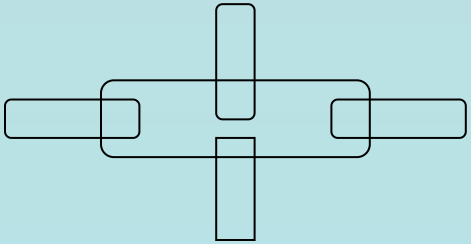
Comparing # of small clips in first molecule to the other molecules

_____ : _____

_____ : _____ _____ : _____



_____ : _____ _____ : _____



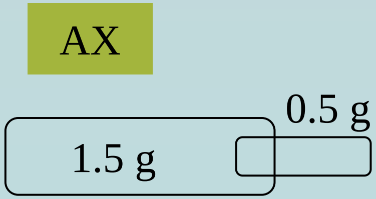
_____ : _____ _____ : _____

Laws of Definite & Multiple Proportion Application

The small paper clip's mass is 0.5 g, the large 1.5 g

Determine the Definite & Multiple Proportions:

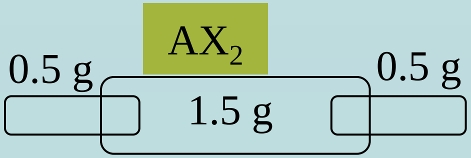
Definite Proportion *Multiple Proportion*



___1___ : ___3___

0.5 g / 1.5 g

[E.g. CO, NO, PbO]

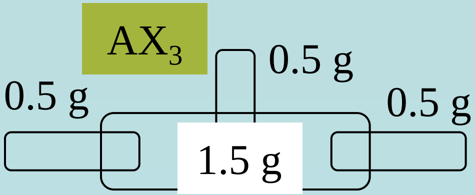


___2___ : ___3___

2(0.5 g) / 1.5 g

___1__ : ___2___

[E.g. CO_2, ClO_2, SO_2, NO_2]

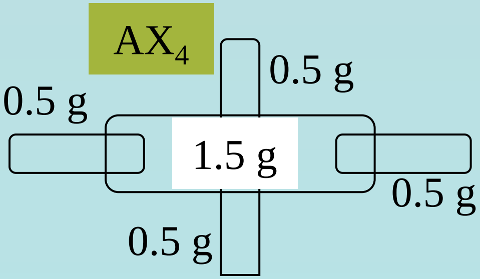


___3___ : ___3___

3(0.5 g) / 1.5 g

___1__ : ___3___

[E.g. CO_3, ClO_3, SO_3, NO_3, PO_3]



___4___ : ___3___

4(0.5 g) / 1.5 g

___1__ : ___4___

[E.g. ClO_4, SO_4, PO_4, CrO_4]

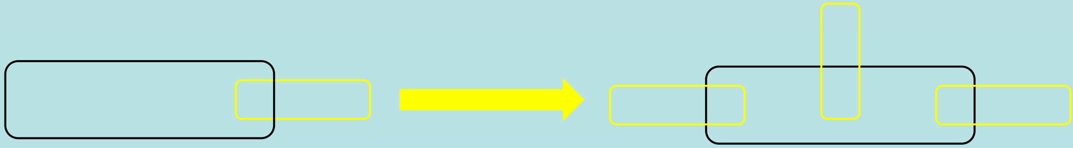
Laws of Definite & Multiple Proportion Application

- ***Definite proportions compares the mass of the elements WITHIN the same molecule***

  (small paper clip : large paper clip)

- ***Multiple proportions compares the mass of same element BETWEEN different molecules***

  (the SMALL paper clip in the first compound to the SMALL paper clip in the other compounds)



Laws of Definite & Multiple Proportion Application

$Cu^{+1}Cl^{-1}$

$Cu^{+2}Cl_2^{-1}$

Definite proportions *compares the mass of the two elements WITHIN the same molecule*

Copper(I) chloride [CuCl] and copper (II) chloride [$CuCl_2$] both contain chlorine. We can compare the mass of copper to chlorine WITHIN each molecule (Definite Proportions).

Multiple proportions *compares the mass of same element BETWEEN different molecules*

We can compare the mass of chlorine to chlorine BETWEEN each molecule (Multiple Proportions).

Laws of Definite & Multiple Proportion Application

Fixed mass of Nitrogen	Empirical Formula	General Formula	Mass of Oxygen reacted with 1 g Nitrogen	Ratio of Oxygen to Oxygen
N_2O	N_2O	A_2B	? 16 g/28 g	?
N_2O_2	NO	AB	? 32 g/28 g	?
N_2O_3	N_2O_3	A_2B_3	? 48 g/28 g	?
N_2O_4	NO_2	AB_2	? 64 g/28 g	?
N_2O_5	N_2O_5	A_2B_5	? 80 g/28 g	?

Chlorate series [give the multiple proportion of each series]

perchlorate (ClO_4^-), chlorate (ClO_3^-), chlorite (ClO_2^-), hypochlorite (ClO^-)

Phosphate series

perphosphate (PO_5^{-3}), phosphate (PO_4^{-3}), phosphite (PO_3^{-3}), hypophosphite (PO_2^{-3})

Chromate series

perchromate (CrO_5^{-2}), chromate (CrO_4^{-2}), chromite (CrO_3^{-2}), hypochromite (CrO_2^{-2})

Laws of Definite & Multiple Proportion Application

			Definite Proportions	Multiple Proportions
Fixed mass of Nitrogen	Empirical Formula	General Formula	Mass of Oxygen reacted with 1 g Nitrogen	Ratio of Oxygen to Oxygen
N_2O	N_2O	A_2B	0.5711 16g/28g	1
N_2O_2	NO	AB	1.1422 32g/28g	2
N_2O_3	N_2O_3	A_2B_3	1.7134 48g/28g	3
N_2O_4	NO_2	AB_2	2.2845 64g/28g	4
N_2O_5	N_2O_5	A_2B_5	2.8557 80g/28g	5

Chlorate series [4:3:2:1]

perchlorate (ClO_4^-), chlorate (ClO_3^-), chlorite (ClO_2^-), hypochlorite (ClO^-)

Phosphate series [5:4:3:2]

perphosphate (PO_5^{-3}), phosphate (PO_4^{-3}), phosphite (PO_3^{-3}), hypophosphite (PO_2^{-3})

Chromate series [5:4:3:2]

perchromate (CrO_5^{-2}), chromate (CrO_4^{-2}), chromite (CrO_3^{-2}), hypochromite (CrO_2^{-2})

Calculating Mass Ratios

Practice problem

Carbon (C) reacts with oxygen (O) to form two compounds.

Compound A contains 2.41 g of carbon for each 3.22 g of oxygen.

Compound B contains 6.71 g of carbon for each 17.9 g of oxygen.

Are these the same compound? What is the lowest whole-number mass ratio of carbon that combines with a given mass of oxygen for compounds A and B?

TRY IT

Calculating Mass Ratios

Practice problem

Carbon (C) reacts with oxygen (O) to form two compounds.

Compound A contains 2.41 g of carbon for each 3.22 g of oxygen.

Compound B contains 6.71 g of carbon for each 17.9 g of oxygen.

First, calculate grams of carbon per gram of oxygen in compound A. (Definite Proportions)

$$\frac{2.41\text{ g C}}{3.22\text{ g O}} = \frac{0.748\text{ g C}}{1.00\text{ g O}}$$

TRY IT

Then, calculate grams of carbon per gram of oxygen in compound B. (Definite Proportions)

$$\frac{6.71\text{ g C}}{17.9\text{ g O}} = \frac{0.375\text{ g C}}{1.00\text{ g O}}$$

Practice problem

Since the definite proportion ratios are not the same, the two compounds are not the same.

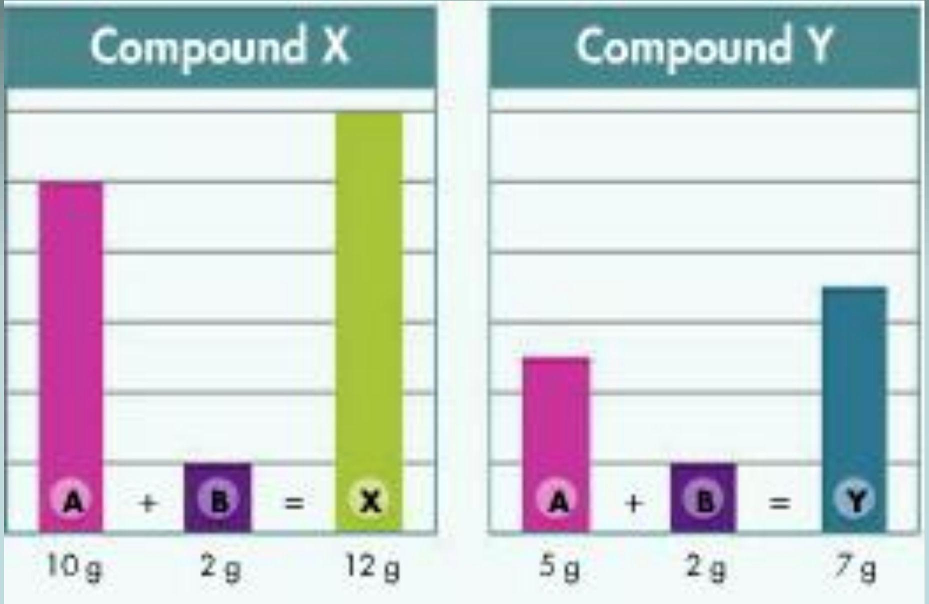
Compound A	0.748:1	C = 12 g/mol	
Compound B	0.375:1	O = 16 g/mol	12/16 = 0.748

Calculate the mass ratio to compare the two compounds.

$$\frac{0.748 \text{ g C}}{0.375 \text{ g O}} = \frac{1.99}{1} \approx \frac{2}{1}$$

Express the mass ratio as the lowest whole-number ratio. The mass ratio of carbon per gram of oxygen in the two compounds is 2:1. These molecules could be CO_2 and CO.

TRY IT

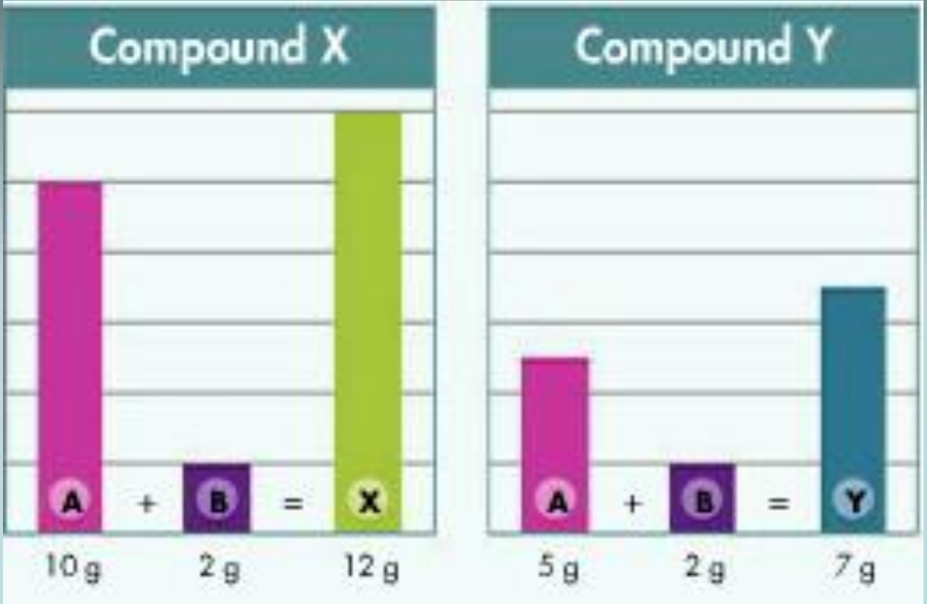


Are compound X and Y the same compound?

What is the mass ratio of element A in the two compounds?

Explain your answers.

TRY IT



Are compound X and Y the same compound?

What is the mass ratio of element A in the two compounds?

Explain your answers.

DEFINITE PROPORTIONS:

Since element B is the same (2 g) in both compounds, we can focus on element A to answer this question.

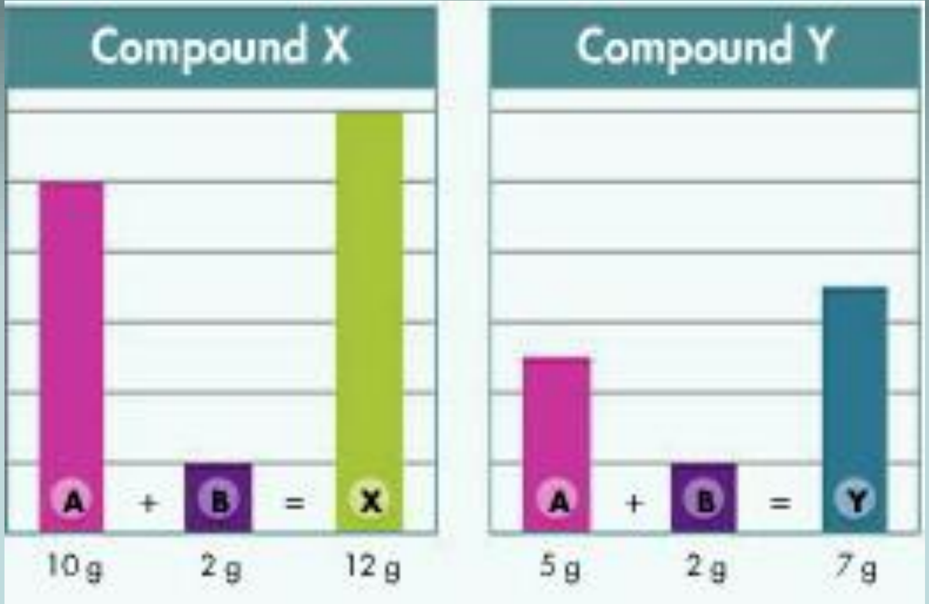
Mass ratio of elements (A:B) →

10 g / 2 g = 5 : 1 in compound X, but

5 g / 2 g = 2.5 : 1 in compound Y,

showing that “**X**” and “**Y**” are DIFFERENT compounds.

TRY IT



Are compound X and Y the same compound?

What is the mass ratio of element A in the two compounds?

Explain your answers.

10 g / 2 g = 5 : 1 in compound X,

5 g / 2 g = 2.5 : 1 in compound Y

MULTIPLE PROPORTIONS:

$$\frac{\text{5 g O “A” (in “X” sample that has 1 g B)}}{\text{2.5 g “A” (in “Y” sample that has 1 g B)}} = \frac{5}{2.5} = \frac{2}{1} = 2:1$$

Compound X → A_2B

Compound Y → AB

Laws of Definite & Multiple Proportion Application

Two compounds contain hydrogen and oxygen. Compound 1 contains 2 grams of hydrogen and 16 grams of oxygen. Compound 2 contains 4 grams of hydrogen and 64 grams of oxygen. Are these compounds the same? If not, what are they? [Show the laws of definite and multiple proportions.]

Laws of Definite & Multiple Proportion Application

Two compounds contain hydrogen and oxygen. Compound 1 contains 2 grams of hydrogen and 16 grams of oxygen. Compound 2 contains 4 grams of hydrogen and 64 grams of oxygen. Are these compounds the same? If not, what are they? [Show the laws of definite and multiple proportions.]

DEFINITE PROPORTIONS:

Compound 1

Hydrogen : Oxygen = 2 g : 16 g = **1:8**

Compound 2

Hydrogen : Oxygen = 4 g : 64 g = **1:16**

Laws of Definite & Multiple Proportion Application

Two compounds contain hydrogen and oxygen. Compound 1 contains 2 grams of hydrogen and 16 grams of oxygen. Compound 2 contains 4 grams of hydrogen and 64 grams of oxygen. Are these compounds the same? If not, what are they? [Show the laws of definite and multiple proportions.]

MULTIPLE PROPORTIONS:

$$\frac{16\text{ g O (per 1 g H)}}{8\text{ g O (per 1 g H)}} = \frac{16}{8} = \frac{2}{1} = 2{:}1$$

The ratio of the mass of oxygen in the two compounds is exactly 2:1 meaning that one molecule has 2 times the oxygen by mass. This is Multiple Proportions.

H_2O *and* H_2O_2

KEY

Atomic Mass → 12.0111

Symbol → **C**

Atomic Number → 6

Electron Configuration → $1s^2 2s^2 2p^2$

Selected Oxidation States → −4 +2 +4

Relative atomic masses are based on ^{12}C = 12.00000

New Designation

Former Designation (prior to 1984 IUPAC decision)

s-block

d-block

Transition Elements

GROUP

Period	*s*-block 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	
1	1.00794 +1 −1 **H** 1 $1s^1$										
2	6.941 +1 **Li** 3 $1s^2 2s^1$	9.01218 +2 **Be** 4 $1s^2 2s^2$									
3	22.98977 +1 **Na** 11 $[Ne]3s^1$	24.305 +2 **Mg** 12 $[Ne]3s^2$									
4	39.0983 +1 **K** 19 $[Ar]4s^1$	40.08 +2 **Ca** 20 $[Ar]4s^2$	44.9559 +3 **Sc** 21 $[Ar]3d^1 4s^2$	47.88 +2 +3 +4 **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 +2 +3 +4 +5 **V** 23 $[Ar]3d^3 4s^2$	51.996 +2 +3 +6 **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 +2 +3 +4 +7 **Mn** 25 $[Ar]3d^5 4s^2$	55.847 +2 +3 **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 +2 +3 **Co** 27 $[Ar]3d^7 4s^2$	58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.54 29 [Ar]3d
5	85.4678 +1 **Rb** 37 $[Kr]5s^1$	87.62 +2 **Sr** 38 $[Kr]5s^2$	88.9059 +3 **Y** 39 $[Kr]4d^1 5s^2$	91.224 +4 **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 +3 +5 **Nb** 41 $[Kr]4d^4 5s^1$	95.94 +3 +6 **Mo** 42 $[Kr]4d^5 5s^1$	(98) +4 +6 +7 **Tc** 43 $[Kr]4d^6 5s^1$	101.07 +3 **Ru** 44 $[Kr]4d^7 5s^1$	102.906 +3 **Rh** 45 $[Kr]4d^8 5s^1$	106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.86 47 [Kr]4d
6	132.905 +1 **Cs** 55 $[Xe]6s^1$	137.33 +2 **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 +4 **Hf** 72 $[Xe]4f^{14} 5d^2 6s^2$	180.948 +5 **Ta** 73 $[Xe]4f^{14} 5d^3 6s^2$	183.85 +6 **W** 74 $[Xe]4f^{14} 5d^4 6s^2$	186.207 +4 +6 +7 **Re** 75 $[Xe]4f^{14} 5d^5 6s^2$	190.2 +3 +4 **Os** 76 $[Xe]4f^{14} 5d^6 6s^2$	192.22 +3 +4 **Ir** 77 $[Xe]4f^{14} 5d^7 6s^2$	195.08 +2 +4 **Pt** 78 $[Xe]4f^{14} 5d^9 6s^1$	196.96 79 [Xe]4f
7	(223) +1 **Fr** 87 $[Rn]7s^1$	226.025 +2 **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		* The sys 103 wil

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2.00000

lation States

s-block
18
0

p-block
GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 0
								4.00260 0 **He** 2 $1s^2$
			10.81 +3 **B** 5 $1s^22s^22p^1$	12.0111 −4 +2 +4 **C** 6 $1s^22s^22p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 $1s^22s^22p^3$	15.9994 −2 **O** 8 $1s^22s^22p^4$	18.998403 −1 **F** 9 $1s^22s^22p^5$	20.179 0 **Ne** 10 $1s^22s^22p^6$
			26.98154 +3 **Al** 13 $[Ne]3s^23p^1$	28.0855 −4 +2 +4 **Si** 14 $[Ne]3s^23p^2$	30.97376 −3 +3 +5 **P** 15 $[Ne]3s^23p^3$	32.06 −2 +4 +6 **S** 16 $[Ne]3s^23p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 $[Ne]3s^23p^5$	39.948 0 **Ar** 18 $[Ne]3s^23p^6$
58.69 +2 +3 **Ni** 28 $[Ar]3d^84s^2$	63.546 +1 +2 **Cu** 29 $[Ar]3d^{10}4s^1$	65.39 +2 **Zn** 30 $[Ar]3d^{10}4s^2$	69.72 +3 **Ga** 31 $[Ar]3d^{10}4s^24p^1$	72.59 −4 +2 +4 **Ge** 32 $[Ar]3d^{10}4s^24p^2$	74.9216 −3 +3 +5 **As** 33 $[Ar]3d^{10}4s^24p^3$	78.96 −2 +4 +6 **Se** 34 $[Ar]3d^{10}4s^24p^4$	79.904 −1 +1 +5 **Br** 35 $[Ar]3d^{10}4s^24p^5$	83.80 0 +2 **Kr** 36 $[Ar]3d^{10}4s^24p^6$
106.42 +2 +4 **Pd** 46 $[Kr]4d^{10}5s^0$	107.868 +1 **Ag** 47 $[Kr]4d^{10}5s^1$	112.41 +2 **Cd** 48 $[Kr]4d^{10}5s^2$	114.82 +3 **In** 49 $[Kr]4d^{10}5s^25p^1$	118.71 +2 +4 **Sn** 50 $[Kr]4d^{10}5s^25p^2$	121.75 −3 +3 +5 **Sb** 51 $[Kr]4d^{10}5s^25p^3$	127.60 −2 +4 +6 **Te** 52 $[Kr]4d^{10}5s^25p^4$	126.905 −1 +1 +5 +7 **I** 53 $[Kr]4d^{10}5s^25p^5$	131.29 0 +2 +4 +6 **Xe** 54 $[Kr]4d^{10}5s^25p^6$
195.08 +2 +4 **Pt** 78 $[Xe]4f^{14}5d^96s^1$	196.967 +1 +3 **Au** 79 $[Xe]4f^{14}5d^{10}6s^1$	200.59 +1 +2 **Hg** 80 $[Xe]4f^{14}5d^{10}6s^2$	204.383 +1 +3 **Tl** 81 $[Xe]4f^{14}5d^{10}6s^26p^1$	207.2 +2 +4 **Pb** 82 $[Xe]4f^{14}5d^{10}6s^26p^2$	208.980 +3 +5 **Bi** 83 $[Xe]4f^{14}5d^{10}6s^26p^3$	(209) +2 +4 **Po** 84 $[Xe]4f^{14}5d^{10}6s^26p^4$	(210) **At** 85 $[Xe]4f^{14}5d^{10}6s^26p^5$	(222) 0 **Rn** 86 $[Xe]4f^{14}5d^{10}6s^26p^6$

IONIZATION ENERGIES AND ELECTRONEGATIVITIES

1	2	13	14	15	16	17	18
313 H 2.2							567 He
125 Li 1.0	215 Be 1.5	191 B 2.0	260 C 2.6	336 N 3.1	314 O 3.5	402 F 4.0	497 Ne
119 Na 0.9	176 Mg 1.2	138 Al 1.5	188 Si 1.9	242 P 2.2	239 S 2.6	300 Cl 3.2	363 Ar
100 K 0.8	141 Ca 1.0	138 Ga 1.6	182 Ge 1.9	226 As 2.0	225 Se 2.5	273 Br 2.9	323 Kr
96 Rb 0.8	131 Sr 1.0	133 In 1.7	169 Sn 1.8	199 Sb 2.1	208 Te 2.3	241 I 2.7	280 Xe
90 Cs 0.7	120 Ba 0.9	141 Tl 1.8	171 Pb 1.8	168 Bi 1.9	194 Po 2.0	At 2.2	248 Rn
Fr 0.7	122 Ra 0.9						

313 ← First Ionization Energy (kcal/mol of atoms)

2.2 ← Electronegativity*

* Arbitrary scale based on fluorine = 4.0

Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium
$(NH_4)^{+1}$