AP Chemistry 2026-2027 Summer Review

Welcome to AP Chemistry. Summer review work is meant to get us off to a running start when fall arrives. You should already know most of the material in this packet from your first-year chemistry class. Nonetheless, START NOW to make your way leisurely through this review. Do not think you should wait until the very end of the summer, so it is "fresh in your mind." The LONGER it is in your mind, the better it will stick. This review is only a brief overview of the different topics you should know. If you need more extensive explanation list the topic in google and research it. Reliable youtuber that explain chemistry very well are; Khan academy, The Organic Chemistry Tutor, and Professor Dave Explains. Other youtuber may NOT be accurate or reliable. Email me with any questions or concerns. I will try to respond ASAP. My email is dying@cherrycreekschools.org

This packet contains topics on

1.) **Nomenclature** – (naming and writing formula) with the **memorization** of common polyatomics and elements. Memorization of names, symbols (chemical formula) and charge is a **must**.
2.) **PEN Tables** – protons, neutrons, electrons, mass number and atomic mass.
3.) **Electron configuration** – long and abbreviated. Configuration of ions.
4.) **Lewis Dot structures and VESPR** – Recognizing VESPR shapes by the structure of compounds.
5.) **Chemical Reactions** – Writing out a chemical reaction and net ionic equations.
6.) **Chemical composition** – Percent composition, empirical and molecular formula.
7.) **Stoichiometry** – Stoichiometry, limiting and percent yield.
8.) **Solution** – Molarity, dilutions, millimoles.
9.) **Gases** – Simple gas laws, ideal gas law. Dalton's law of partial pressure.

Nomenclature

You will be more successful in AP chemistry if you can name chemicals from their formulas, and if you can write chemical formulas from the name of the chemical. You don't need to know all polyatomic ions − just a short list will be helpful. You should be able to do this with only the assistance of a periodic table, after *memorizing* the polyatomic ions in the charts below.

Polyatomic Ions -

Memorize the shaded ions (and learn the pattern so you can easily memorize their companions). Or just memorize all of them.

By learning the four shaded "-ate" ions in the table to the right **and** knowing that one less oxygen (same charge) turns the name to −*ite*, **and** two less oxygens (when possible) turns the name to *hypo*−xxx−ite **and** one more oxygen (when possible) turns the name to *per*−xxx−ate will make learning all eighteen ions in the chart below as easy as learning just four.

Memorize the six extra polyatomic ions in the second table below, and don't forget ammonium in the table by itself.

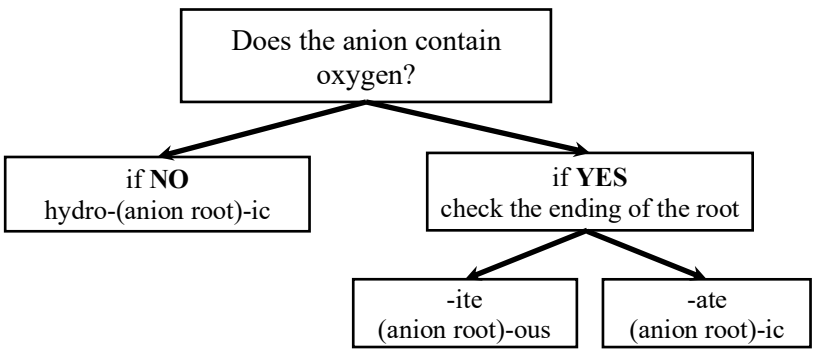
Polyatomic Ions to Memorize *(Use the pattern to help)*			
hypo- (2 less O)	**-ite (1 less O)**	**-ate**	**per- (1 more O)**
	nitrite NO_2^-	nitrate NO_3^-	
	sulfite SO_3^{2-}	sulfate SO_4^{2-}	
	phosphite PO_3^{3-}	phosphate PO_4^{3-}	
hypochlorite ClO^-	chlorite ClO_2^-	chlorate ClO_3^-	perchlorate ClO_4^-
hypobromite BrO^-	bromite BrO_2^-	bromate BrO_3^-	perbromate BrO_4^-
hypoiodite IO^-	iodite IO_2^-	iodate IO_3^-	periodate IO_4^-

Odd Companions or No Companion	
hydroxide OH^-	
cyanide CN^-	
acetate $C_2H_3O_2^-$	
carbonate CO_3^{2-}	bicarbonate HCO_3^-
permanganate MnO_4^- *purple color*	ammonium NH_4^+

Acids and Bases

You will need to be able to name acids. Knowing your polyatomic ions is critical in naming the acids. Use the chart below to review the pattern and method of naming.

Demystifying the Naming of Acids



DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1																	18
1 **H** 1.008	2											13	14	15	16	17	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.30	3	4	5	6	7	8	9	10	11	12	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.97	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc**	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57–71 *	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po**	85 **At**	86 **Rn**
87 **Fr**	88 **Ra**	89–103 †	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ds**	111 **Rg**	112 **Cn**	113 **Nh**	114 **Fl**	115 **Mc**	116 **Lv**	117 **Ts**	118 **Og**

*Lanthanoids	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm**	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
†Actinoids	89 **Ac**	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

You should learn your polyatomic ions well enough to write these names and formulas without looking at the polyatomic ion chart. Use only the periodic table in this packet. (ANSWERS are on the following page)

Write chemical formulas for the following names.

1. sodium sulfite _____
2. copper(II) nitrate _____
3. sulfur trioxide _____
4. sodium hydroxide _____
5. nitrogen dioxide _____
6. aluminum perchorate _____
7. silver sulfide _____
8. carbonic acid _____
9. ammonium phosphate _____
10. potassium permanganate _____
11. lead(II) cyanide _____
12. calcium acetate _____
13. nitrous acid _____
14. hydroiodic acid _____
15. sodium bicarbonate _____
16. nickel(III) iodate _____
17. chloric acid _____
18. aluminum sulfite _____
19. phosphorous acid _____
20. barium hydroxide _____

Write names for the following formulas.

21. $Sr(CN)_2$ _____
22. H_3PO_4 _____
23. $ZnSO_4$ _____
24. $Cu(SO_3)_2$ _____
25. H_2SO_4 _____
26. $AuOH$ _____
27. K_2CO_3 _____
28. $NaHCO_3$ _____
29. $HClO_2$ _____
30. $AgNO_2$ _____
31. $HBrO$ _____
32. KOH _____
33. $HC_2H_3O_2$ _____
34. $Ni(BrO_2)_3$ _____
35. HBr _____
36. $NaMnO_4$ _____
37. P_2O_5 _____
38. H_3PO_4 _____
39. $(NH_4)_2SO_4$ _____
40. $Ni(OH)_2$ _____

1. sodium sulfite **Na_2SO_3**
2. copper(II) nitrate **$Cu(NO_3)_2$**
3. sulfur trioxide **SO_3**
4. sodium hydroxide **NaOH**
5. nitrogen dioxide **NO_2**
6. aluminum perchorate **$Al(ClO_4)_3$**
7. silver sulfide **Ag_2S**
8. carbonic acid **H_2CO_3**
9. ammonium phosphate **$(NH_4)_3PO_4$**
10. potassium permanganate **$KMnO_4$**
11. lead(II) cyanide **$Pb(CN)_2$**
12. calcium acetate **$Ca(C_2H_3O_2)_2$**
13. nitrous acid **HNO_2**
14. hydroiodic acid **HI**
15. sodium bicarbonate **$NaHCO_3$**
16. nickel(III) iodate **$Ni(IO_3)_3$**
17. chloric acid **$HClO_3$**
18. aluminum sulfite **$Al_2(SO_3)_3$**
19. phosphorous acid **H_3PO_3**
20. barium hydroxide **$Ba(OH)_2$**
21. $Sr(CN)_2$ **strontium cyanide**
22. H_3PO_4 **phosphoric acid**
23. $ZnSO_4$ **zinc sulfate**
24. $Cu(SO_3)_2$ **copper(IV) sulfite**
25. H_2SO_4 **sulfuric acid**
26. AuOH **gold(I) hydroxide**
27. K_2CO_3 **potassium carbonate**
28. $NaHCO_3$ **sodium bicarbonate**
29. $HClO_2$ **chlorous acid**
30. $AgNO_2$ **silver nitrite**
31. HBrO **hypobromous acid**
32. KOH **potassium hydroxide**
33. $HC_2H_3O_2$ **acetic acid**
34. $Ni(BrO_2)_3$ **nickel(III) bromite**
35. HBr **hydrobromic acid**
36. $NaMnO_4$ **sodium permanganate**
37. P_2O_5 **diphosphorus pentoxide**
38. H_3PO_4 **phosphoric acid**
39. $(NH_4)_2SO_4$ **ammonium sulfate**
40. $Ni(OH)_2$ **nickel(II) hydroxide**

On the periodic table, each element has a great deal of information about it. The **Atomic number** is a whole number (no decimals) and it represents the number of **protons** an element has. For a neutral atom the number protons equal the number of electrons. If an atom has a charge, it is known as an **ion.** If an atom has more electrons than protons, it means it is a negative ion. If an atom has less electrons than protons, it means it is a positive ion. Only the number of electrons can change for a certain element. If the number of protons change then the atom is a different element. The decimal number is the **atomic mass**. The atomic mass represents two important aspects of an atom. First, it represents the average number of protons and neutrons represented in the world. Second, it represents the average atomic mass in amu. This is the amount of grams needed, to weigh out, to obtain one mole of that element. The mass number is atomic mass rounded to a whole number. To calculate the number of neutrons, it is the number of protons subtracted from the mass number.

Electron configuration

The electron configuration is the standard notation used to describe the electronic structure of an atom. Under the orbital approximation, we let each electron occupy an orbital, which can be solved by a single wavefunction. The electron configuration follows three set of three rules: the Aufbau Principle, the Pauli-Exclusion Principle, and Hund's Rule.

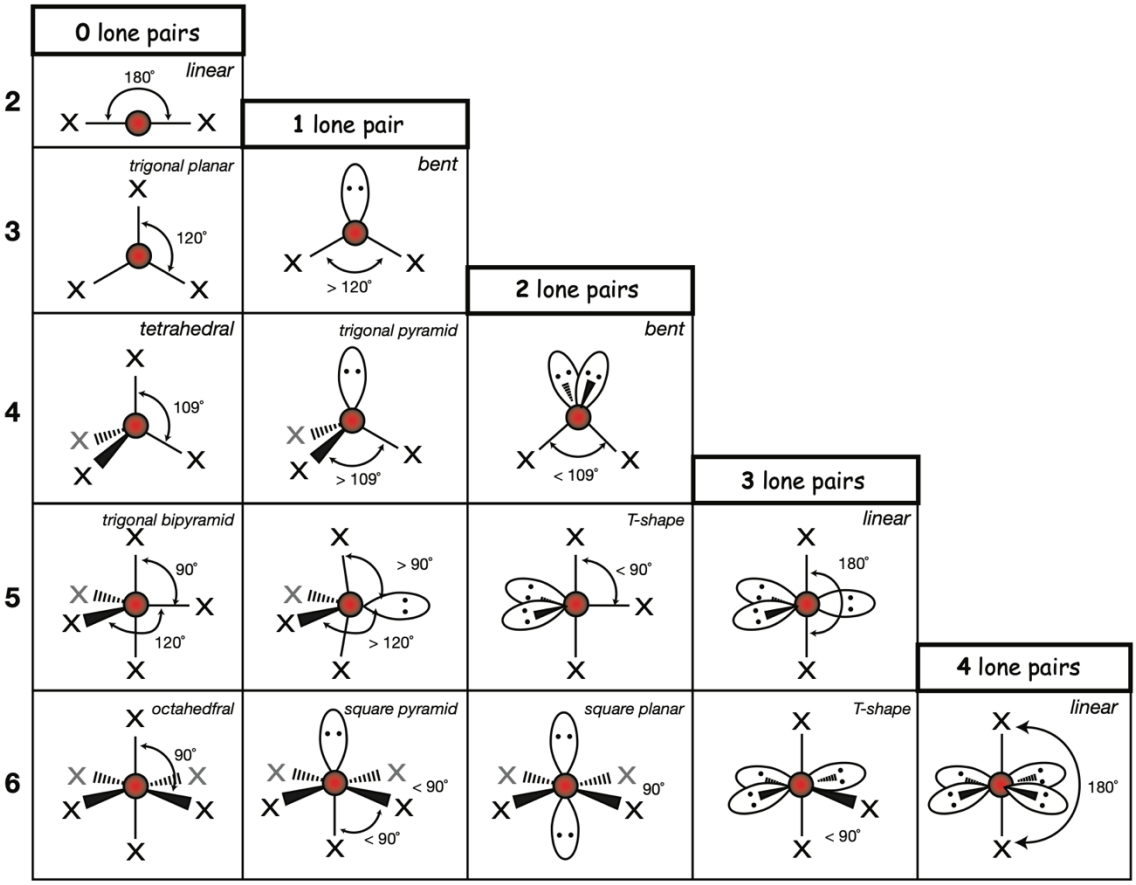
- The *Aufbau Principle* states that electron's occupy orbitals in order of increasing energy.
- *Hund's Rule* states that electrons must occupy the first empty orbitals before double occupying them.
- *Pauli Exclusion Principle* states that an atomic orbital that contains two electrons must have opposite spins.

Lewis Dot Structures

A Lewis Structure is a very simplified representation of the valence shell electrons in a molecule. It is used to show how the electrons are arranged around individual atoms in a molecule. Electrons are shown as "dots" or for bonding electrons as a line between the two atoms. The goal is to obtain the "best" electron configuration, *i.e.* the octet rule and formal charges need to be satisfied. **Valence electrons** are the number of electrons that are available in the last outer electron shell.

Valence Shell Electron Pair Repulsion (VSEPR)

The VSEPR theory is used to predict the shape of the molecules from the electron pairs that surround the central atoms of the molecule. The theory was first presented by Sidgwick and Powell in 1940. The VSEPR theory assumes that the molecule will take shape such that electronic repulsion in the valence shell of that atom is minimized.



1. Complete the following table to demonstrate your knowledge of sub-atomic particles

symbol	# of protons	# of neutrons	# of electrons	atomic #	mass #	charge
		24	21			0
			18	15	31	
$^{13}_{6}C$					13	
	17				35	1−
			23	26	58	

2. Write complete electron configurations for the following particles.
   a. S _____
   b. Zr _____
   c. P^{3-} _____
   d. Cr^{2+} _____

3. Write condensed electron configurations for the following particles.
   a. Al _____
   b. P _____
   c. Sr _____
   d. Pb _____

4. Complete the table on VSEPR

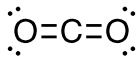
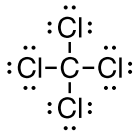
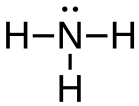
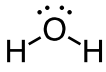
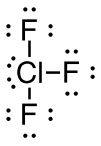
Compound	Ve-	Lewis Dot Structure	Molecular Geometry
CO_2			
CH_4			
NH_3			
H_2O			
PCl_5			

1. Complete the following table to demonstrate your knowledge of subatomic particles

symbol	# of protons	# of neutrons	# of electrons	atomic #	mass #	charge
Sc	21	24	21	21	45	0
P^{3-}	15	16	18	15	31	3−
$^{13}_{6}C$	6	7	6	6	13	0
Cl^-	17	18	18	17	35	1−
$^{58}_{26}Fe^{3+}$	26	32	23	26	58	3+

2. Write complete electron configurations for the following particles.
   a. S $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
   b. Zr $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ \ 4s^2\ 3d^{10}\ 4p^6\ \ 5s^2\ 4d^2$
   c. P^{3-} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
   d. Cr^{2+} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4\ 3d^4$ (Cr atom will lose its valence "s" electrons because they are further from the nucleus.)
3. Write condensed electron configurations for the following particles.
   a. Al $[Ne]\ 3s^2\ 3p^1$
   b. Ge $[Ar]\ 4s^2\ 3d^{10}\ 4p^2$
   c. Sr $[Kr]\ 5s^2$
   d. Pb $[Xe]\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^2$

4. Complete the table on VSEPR

Compound	Ve-	Lewis Dot Structure	Molecular Geometry
CO_2	16ve-		Linear
CCl_4	32ve-		Tetrahedral
NH_3	8ve-		Trigonal Pyramidal
H_2O	8ve-		Bent
ClF_3	28ve-		T-Shaped

Chemical Reactions

There are 5 main reaction types.

Synthesis (S) is a reaction where two reactants forming one product.

Decomposition (D) is a reaction where one reactant breaks down into 2 or more products.

Combustion (C)is a reaction where a single element or compound combines with oxygen to form carbon dioxide and water.

Single replacement (SR) is a reaction where a single element replaces a similar element in a compound.

Double replacement (DR) is a reaction where two ionic compounds switch.

Not only is it important to recognize these reactions but it's also important to predict these reactions by looking at the reactants.

Net ionic equation is a chemical equation that shows only those elements, compounds, and ions that are directly involved in the chemical reaction.

5. Predict and balance the following reaction and list the reaction type.

Reaction type	
a.	$Mg_{(s)} + I_{2(l)} \rightarrow$
b.	$Ba(NO_3)_{2(aq)} + Na_2SO_{3(aq)} \rightarrow$
c.	$CH_{4(g)} + O_{2(g)} \rightarrow$
d.	$Na_{(s)} + MgSO_{4(aq)} \rightarrow$
e.	$FeCl_{3(s)} \rightarrow$
f.	Solid Calcium reacts with aqueous nickel(III) iodide
g.	Dilute Sulfuric acid reacts with aqueous sodium hydroxide
h.	Propane gas reacts with oxygen gas
i.	Solid sodium oxide decomposes
j.	Solid potassium reacts with nitrogen gas.

Net ionic equation

6. Write the complete ionic equation and the net ionic equation for the following reactions
   a. Sodium sulfate reacts with iron(III) nitrate

   b. Sodium reacts with silver nitrate

   c. Potassium carbonate reacts with magnesium chloride

5. Predict and balance the following reaction and list the reaction type.

Reaction type	
a. S	$Mg_{(s)} + I_{2(l)} \rightarrow MgI_{2(s)}$
b. DR	$Ba(NO_3)_{2(aq)} + Na_2SO_{3(aq)} \rightarrow BaSO_{3(s)} + 2NaNO_{3(aq)}$
c. C	$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$
d. SR	$Li_{(s)} + MgSO_{4(aq)} \rightarrow Li_2SO_{4(aq)} + Mg_{(s)}$
e. D	$2FeCl_{3(s)} \rightarrow 2Fe_{(s)} + 3Cl_{2(g)}$
f. SR	$3Ca_{(s)} + 2NiI_{3(aq)} \rightarrow 3CaI_{2(aq)} + 2Ni_{(s)}$
g. DR	$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow 2H_2O_{(l)} + Na_2SO_{4(aq)}$
h. C	$C_3H_{8(l)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$
i. D	$2Na_2O_{(s)} \rightarrow 4Na_{(s)} + O_{2(g)}$
j. S	$6K_{(s)} + N_{2(g)} \rightarrow 2K_3N_{(s)}$

Net ionic equation

6. Write the complete ionic equation and the net ionic equation for the following reactions
   a. Sodium sulfate reacts with iron(III) nitrate
      Complete: $Na_2SO_{4(aq)} + Fe(NO_3)_{3(aq)} \rightarrow Fe_2(SO_4)_{3(s)} + NaNO_{3(aq)}$

      Net: $SO_4^{2-}{}_{(aq)} + Fe^{3+}{}_{(aq)} \rightarrow Fe_2(SO_4)_{3(s)}$
   b. Sodium reacts with silver nitrate
      Complete: $Na_{(s)} + AgNO_{3(aq)} \rightarrow Ag_{(s)} + NaNO_{3(aq)}$

      Net: $Na_{(s)} + Ag^{+}{}_{(aq)} \rightarrow Ag_{(s)} + Na^{+}{}_{(aq)}$
   c. Potassium carbonate reacts with magnesium chloride
      Complete: $K_2CO_{3(aq)} + MgCl_{2(aq)} \rightarrow 2KCl_{(aq)} + MgCO_{3(s)}$

      Net: $CO_3^{2-}{}_{(aq)} + Mg^{2+}{}_{(aq)} \rightarrow MgCO_{3(s)}$

Percent Composition

Laboratory experiments can give the masses of the various elements contained in the total mass of the compound. This common practice is called *elemental analysis* or *mass percent composition* or more simply percent composition. Example, H_2O: 2 (1.01 g/mole) + 16.00 g/mole = 18.02 g/mole total (these numbers are the molar masses from the periodic chart.)

$$H: \frac{2.02\ g}{10.02}\ x\ 100 = 11.02\% \qquad O: \frac{16.00 g}{18.02}\ x\ 100 = 89.88\%$$

Thus water is 11 % hydrogen and 89 % oxygen

Empirical and Molecular Formulas

As you know, the chemical formulas for molecular compounds are not always written in the lowest whole number ratios. We have often used formaldehyde CH_2O and sugar $C_6H_{12}O_6$ as an example. Because of this, the elemental analysis to determine empirical formulas would not allow a chemist to distinguish between sugar and formaldehyde. Another analysis tool, mass spectroscopy would be needed to give one more piece of information: the molar mass of the particular compound being analyzed. So the first 4 steps below will help determine the empirical formula, steps 5-6 must be added to determine the molecular formula.

1. Divide each mass or mass percentage by the molar mass of the element, which will give the number of moles of each element.
2. Divide the results from step 1 by whichever number of moles is the smallest. This maintains the mole ratios from step 1 but bases them on the least abundant element being 1.
3. If some results are far from being whole numbers, multiply all the moles through by a common factor that will convert all the mole amounts to whole numbers or near whole numbers.
4. Round each mole amount to the nearest whole number.
5. If a molar mass is given for the compound, calculate the molar mass for the empirical formula just established from step 4. If the molar mass of the empirical formula is the same as the molar mass of the compound given in the problem, then the empirical formula and the molecular formula are one and the same.
6. If the molar mass of the empirical formula is smaller than the molar mass of the compound, divide the two to determine the whole number factor that the empirical formula must be multiplied by to determine the molecular formula.

Sample Problem

Determine the empirical formula for some compound that was analyzed to be 1.33 g of carbon,0.22 g of hydrogen, and 1.78 g of oxygen. Determine the molecular formula for this compound if the molar mass was measured and found to be 180 g/mole.

- First do step 1 as outlined above.

$$C: 1.33\ g\ x\ \frac{1\ mol}{12.01\ g} = 0.111\ mol \qquad H: 0.22\ g\ x\ \frac{1\ mol}{1.01\ g} = 0.219\ mol \qquad O: 1.78\ g\ x\ \frac{1\ mol}{16.00\ g} = 0.111\ mol$$

- Proceed to step 2.

$$C: \frac{0.111\ mol}{0.111\ mol} = 1 \qquad H: \frac{0.219\ mol}{0.111\ mol} = 2 \qquad O: \frac{0.111 mol}{0.111 mol} = 1$$

  Voilà. The empirical formula is CH_2O

- Since steps 3 and 4 are not necessary, proceed to step 5
  - For CH_2O molar mass = 30 g/mole which is of course not the same as 180 g/mole
- Proceed to step 6
- $\frac{180}{30} = 6$
- Therefore when the factor of 6 is distributed through the empirical formula CH_2O
- Voilà. The empirical formula converts to $C_6H_{12}O_6$

7. Bismuth subsalicylate, is the active ingredient in Pepto-Bismol which is used to treat upset stomachs. This chemical has the formula $C_7H_5BiO_4$.

    a. Calculate the percent composition of bismuth subsalicylate.

    b. If each tablet of the medication contains 262 milligrams of $C_7H_5BiO_4$ calculate the mass of bismuth in 2 tablets.

8. Determine the empirical and molecular formula of benzene which contains only carbon and hydrogen and is 7.74% hydrogen by mass. The molar mass of benzene is 78.1 g/mol.

9. 6.394 g of compound used as a drying agent is analyzed and determined to be 2.788 g phosphorus and 3.606 g oxygen. The molar mass is approximately 284 g/mol. Determine the empirical and molecular formulas of this compound. What is the name of this compound?

7. Bismuth subsalicylate, is the active ingredient in Pepto-Bismol which is used to treat upset stomachs. This chemical has the formula $C_7H_5BiO_4$.

   a. Calculate the percent composition of bismuth subsalicylate.

   $C_7H_5BiO_4$ $7(12.01g) + 5(1.008g) + (208.98g) + 4(16g) = 362.09\ g$

   $C\ \frac{84.07}{362.09}\ x\ 100 = 23.22\%$ $H\ \frac{5.04}{362.09}\ x\ 100 = 1.39\ \%$

   $Bi\ \frac{208.98}{362.09}\ x\ 100 = 57.71\%$ $H\ \frac{64}{362.09}\ x\ 100 = 17.68\ \%$

   b. If each tablet of the medication contains 262 milligrams of $C_7H_5BiO_4$ calculate the mass of bismuth in 2 tablets.

   $2\ x\ 262 = 524\ g\ C_7H_5BiO_4$ $524\ g\ C_7H_5BiO_4\ x\ 0.5771 = 302.4\ g\ Bi$

8. Determine the empirical and molecular formula of benzene which contains only carbon and hydrogen and is 7.74% hydrogen by mass. The molar mass of benzene is 78.1 g/mol.

   $100\%\ total - 7.74\%H = 92.26\%C$

   C $92.26\ g\ x\ \frac{1\ mol}{12.01g} = 7.68\ mol.\ Thus\ CH\ 12.01 + 1.008 = 13.018$

   H $7.74\ g\ x\ \frac{1\ mol}{1.08g} = 7.68\ mol.$ $\frac{78.1}{13.018} = 6\ Thus\ C_6H_6$

   Empirical formula: CH and molecular formula: C_6H_6

9. 6.394 g of compound used as a drying agent is analyzed and determined to be 2.788 g phosphorus and 3.606 g oxygen. The molar mass is approximately 284 g/mol. Determine the empirical and molecular formulas of this compound. What is the name of this compound?

   P $2.788\ g\ x\ \frac{1\ mol}{30.97g} = 0.090\ mol.$ $\frac{0.090}{0.090} = 1\ x\ 2 = 2$

   O $3.606\ g\ x\ \frac{1\ mol}{16g} = 0.225\ mol.$ $\frac{0.225}{0.090} = 2.5\ x\ 2 = 5\ Thus\ P_2O_5$

   $2(30.97) + 5(16) = 142,$ $\frac{284}{142} = 2. Thus\ P_5O_{10}\ tetraphosphorus\ decoxide$

   Empirical formula P_2O_5 and molecular formula P_4O_{10}

A Typical Plan for Solving Stoichiometry Problems

There is a basic pattern to all stoichiometry problems, with variations depending on what information is given and what questions must be answered. You are using dimensional analysis so be sure to set up your calculations with the starting units on top and is cancelled out with the same units on the bottom. You should end the desired units and substance on the top of the last conversion.

A. You must start with a balanced equation.
B. Convert the units of any starting substances into moles. (USE Molar Mass (g/mol) complete this calculation) Since the stoichiometric RATIO – coefficients from the balanced equation – is in moles, you must convert the problem to moles.
C. Reread the problem to determine the information that you need to calculate. Use the stoichiometric RATIO to convert from a known substance to the desired substance that you need to answer the question. Note that the RATIO is set up with the known substance on the bottom (so it will cancel out) and with the desired substance on the top.
D. If necessary, convert any answers back into the desired units; grams, molecules, particles, volume, etc.

If your problems only involve moles, then you can skip steps B and D.

Sample Problem

Lithium hydroxide is used in space vehicles to remove exhaled carbon dioxide from the living environment by forming solid lithium carbonate and liquid water. What mass of gaseous carbon dioxide can be absorbed by 1.00. kg of lithium hydroxide?

STEP A. balanced equation: $2\ LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$

Notice that the starting info is given in kilograms, so 1.00 kg should be converted to grams. 1.00 kg = 1000 grams

$$1.00\ x\ 10^3\ g\ LiOH\ x\ \frac{1\ mol}{23.99g}\ x\ \frac{1\ mol\ CO_2}{2\ mol\ LiOH}\ x\ \frac{44.01\ g\ CO_2}{1\ mol\ CO_2} = 917\ g\ CO_2$$

Steps in the dimensional analysis: B. C. D.

STEP B. Change to moles using the molar mass of LiOH
STEP C. Change from moles of LiOH to moles of CO_2 using the coefficients from the balanced equation.
STEP D. Change from moles of CO_2 back to grams of CO_2 using the molar mass of CO_2.

Problem Solving Plan - Limiting Reactant and Percent Yield

For limiting reactant problems, the problem will give you information about two reactants as opposed to information given for only reactant and an assumption that the other reactant is present in excess.

A. You must always start with a balanced equation.
B. If it is a limiting reactant problem.... Determine which reactant LIMITS.
C. First you *must* change your mass values to moles. NOTE: The mathematical trick to determine which reactant limits is to divide the moles of each reactant by the coefficient (from the balanced equation) associated with that reactant. The number that comes out the smallest indicates which reactant is the limiting one. The limiting reactant is the one that you must base all your other calculations on because it is the substance that limits how much of everything else can be made or is needed.
D. Solve the problem using the same steps for Stoichiometry problems above based on the limiting reactant.
E. Of course, the other reactant (if there's only two) will be the excess reactant, and some of it will be left over. By knowing which reactant limits and which is excess, use the limiting reactant to set up a stoichiometric RATIO, to determine the mass of the excess reactant that is actually needed to do the reaction. Then, subtract the mass of reactant that you just calculated was needed, from the amount of excess reactant started with, to determine the mass of excess reactant that is left over.
F. Determining Percent Yield- After determining the LR, use the RATIO to calculate the theoretical amount of the product for which you need a yield.
G. The experimental amount (actually produced) will be given in the problem. Use it to set up the equation below and determine the percent yield:

$$\frac{\boldsymbol{Experimental}}{\boldsymbol{Theoretical}}\ \boldsymbol{x\ 100\% = Percent\ Yield}$$

10. Solutions of nickel(II) chloride and potassium phosphate will react to produce a light green precipitate.
    a. Write a balanced overall chemical equation to represent this reaction.
    b. What mass of potassium phosphate in solution would be required to react completely with 0.875 g of nickel(II) chloride in solution?
    c. Calculate the theoretical mass of nickel(II) phosphate that could be produced.
    d. Convert the overall equation to the net ionic equation.

Solution	Concentration (Molarity)	Volume (Liters)
$Na_2S_2O_3$	0.500	250.
NOCl	2.00	150.
NaOH	0.600	175

11. Gallium metal reacts with perchloric acid. *Assume that at room conditions, 24.0 L is the volume of 1.00 mole of gas.*
    a. Write both overall and net ionic balanced equations to represent this reaction.
    b. If 2.25 L of hydrogen gas were collected, what mass of gallium metal was dropped into the acid solution?

12. Aluminum will cause copper to reduce (react with) a solution of copper(II) chloride.
    a. Write a balanced net ionic chemical equation to represent this reaction.
    b. Is 5.00 g of aluminum enough aluminum to reduce all of the copper(II) ions from 750. ml of a 0.500 M solution?
    c. If 5.00 g of aluminum is more than enough, what mass would be left over? OR if 5.00 g of aluminum is not enough, what is the additional mass of aluminum that would be needed to remove all of the copper(II) ions from solution?

13. Hydrochloric acid reacts with solid magnesium hydroxide.
    a. Write a balanced overall chemical equation to represent this reaction.
    b. What volume, in milliliters, of 0.25 M hydrochloric acid solution would be required to completely react with 4.56 g of magnesium hydroxide?
    c. Convert the balanced overall equation to a net ionic equation.

14. 1.65 g of zinc is dropped into 150. ml of 0.250 M of hydrobromic acid.
    a. Write both overall and net ionic balanced chemical equations to represent this reaction.
    b. Which reactant is the limiting reactant in this chemical reaction?
    c. Calculate the theoretical mass of solid zinc bromide that should be produced.
    d. If Consuela and Pete were able to produce 3.67 g of the zinc bromide, what is their percent yield?

15. Eldon and Sally were preparing a sulfuric acid solution for a lab and they needed 500. mL of 0.045 M
    a. Calculate the volume of 3.0 M solution that Eldon and Sally should measure out into the 500. mL volumetric flask.
    b. What is the molarity of H^+ ions for the solution that Eldon and Sally prepared?
    c. What are the number of millimole of H^+ ions that are in Eldon and Sally's 500. mL of 0.045 M sulfuric acid solution?

16. Nitric acid will react with a sodium carbonate solution.
    a. Write a balanced overall equation to represent this reaction. (Hint: one of the products is a phantom, and will turn into two products. Refer to page 8 of this packet for more information.)
    b. What volume of 0.25 M nitric acid would be required to react completely with 245 ml of 0.38 M of the sodium carbonate solution.

$$Na_2S_2O_{3(aq)} + 4NaOCl_{(aq)} + 2NaOH_{(aq)} \rightarrow 2Na_2SO_{4(aq)} + 4\,NaCl_{(aq)} + H_2O_{(L)}$$

17. Answer the following questions about the balanced redox equation shown above.
    a. The student combines the solutions shown in the table to the right. Determine the limiting reactant.
    b. How many moles of water would be produced during this reaction?
    c. Convert the overall equation shown above into a net ionic equation.

Substance	**Amount**
$Na_2S_2O_3$	250 mL @ 0.5M
NaOCl	150 mL @ 2.00M
NaOH	175mL @ 0.60M

10. Solutions of nickel(II) chloride and potassium phosphate will react to produce a light green precipitate.
    a. $3NiCl_{2(aq)} + 2K_3PO_{4(aq)} \rightarrow 6KCl_{(aq)} + Ni_3(PO_4)_{2(s)}$
    b. $0.875\ g\ NiCl_2\ x\ \frac{1\ mol}{129.59\ g}\ x\ \frac{2\ mol\ K_3PO_4}{3\ mol\ NiCl_2}\ x\ \frac{212.27\ g}{1\ mol} = 0.956\ g\ K_3PO_4$
    c. $0.875\ g\ NiCl_2\ x\ \frac{1\ mol}{129.59\ g}\ x\ \frac{1\ mol\ Ni_3(PO_4)_2}{3\ mol\ NiCl_2}\ x\ \frac{366{,}01\ g}{1\ mol} = 0.824\ g\ Ni_3(PO_4)_2$
    d. $3Ni^{2+} + 2PO_4^{3-} \rightarrow Ni_3(PO_4)_2$

11. Gallium metal reacts with an aqueous perchloric acid solution. *At room conditions, 24.0 L is the volume of 1.00 mole of gas.*
    a. Overall: $2Ga_{(s)} + 6HClO_{4(aq)} \rightarrow 2Ga(ClO_4)_{3(aq)} + 3H_{2(g)}$ Net: $2Ga_{(s)} + 6H^+_{(aq)} \rightarrow 2Ga^{3+}_{(aq)} + 3H_{2(g)}$
    b. $2.25\ L\ H_2\ x\ \frac{1\ mol}{24.0\ L}\ x\ \frac{2\ mol\ Ga}{3\ mol\ H_2}\ x\ \frac{69.72\ g}{1\ mol} = 4.36\ g\ Ga$

12. Aluminum will cause copper to reduce from a solution of copper(II) chloride.
    a. $2Al_{(s)} + 3Cu^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Cu_{(s)}$
    b. $0.5M\ x\ 0.75\ L\ x\ \frac{2\ mol}{3\ mol\ Cu^{2+}}\ x\ \frac{26.98\ g}{1\ mol} = 6.745\ g\ Al\ needed$, thus 5.00 g of aluminum would NOT be enough.
    c. 6.745g needed − 5.00g provided = 1.74 g (or 1.75 g) more aluminum would be needed

13. Hydrochloric acid reacts with solid magnesium hydroxide.
    a. $2HCl_{(aq)} + Mg(OH)_{2(s)} \rightarrow 2H_2O_{(l)} + MgCl_{2(aq)}$
    b. $4.56\ g\ Mg(OH)_2\ x\ \frac{1\ mol}{58.33\ g}\ x\ \frac{2\ mol\ HCl}{3\ mol\ Mg(OH)_2}\ x\ \frac{1\ L}{0.25\ mol} = 0.625\ L\ HCl$
    c. This is 625 ml of hydrochloric acid
    (Remember that molarity means moles/Liter, thus it is used in the dimensional analysis upside down.)
    d. $2H^+_{(aq)} + Mg(OH)_{2(s)} \rightarrow 2H_2O_{(l)} + Mg^{2+}_{(aq)}$

14. 1.650 g of zinc is dropped into 150. ml of 0.250 M of hydrobromic acid.
    a. Overall: $2HBr_{(aq)} + Zn_{(s)} \rightarrow 2H_{2(g)} + ZnBr_{2(aq)}$ Net: $2H^+_{(aq)} + Zn_{(s)} \rightarrow 2H_{2(g)} + Zn^{2+}_{(aq)}$
    b. $0.25\ M\ x\ 0.15\ L = 0.0375\ mol\ HBr \rightarrow 0.0375\ mol\ HBr\ x\ \frac{1\ mol\ Zn}{2\ mol\ HBr}\ x\ \frac{65.38\ g\ Zn}{1\ mol\ Zn} = 1.226\ g\ Zn$
    c. $0.0375\ mol\ HBr\ x\ \frac{1\ mol\ ZnBr_2}{2\ mol\ HBr}\ x\ \frac{225.18\ g}{1\ mol\ ZnBr_2} = 4.22\ g\ ZnBr_2$ Thus the HBr acid solution is limiting.
    d. $\frac{Experimental}{Theoretical} = \frac{3.67\ g\ ZnBr_2}{4.22\ g\ ZnBr_2}\ x\ 100 = 87.0\%$

15. Eldon and Sally were preparing a sulfuric acid solution for a lab and they needed 500. ml of 0.045 M
    a. $M_1V_1 = M_2V_2$, $3.0M \times V_2 = 0.045M \times 500mL$, $V_2 = 7.5\ mL$
    b. $0.045\ M\ H_2SO_4\ x\ \frac{2\ mol\ H^+}{1\ mol\ H_2SO_4} = 0.090\ M\ H^+$
    c. $0.090\ M\ H^+ \times 500\ mL = 45$ millimol

16. Nitric acid will react with a sodium carbonate solution.
    a. $2HNO_{3(aq)} + Na_2CO_{3(aq)} \rightarrow 2NaNO_{3(aq)} + (H_2CO_3\ decomposes\ to\ \Rightarrow)\ H_2O_{(l)} + CO_{2(g)}$
    b. $0.38\ \frac{mol}{L}(M)\ x\ 0.245L\ Na_2CO_3\ x\ \frac{2\ mol\ HNO_3}{1\ mol\ Na_2CO_3}\ x\ \frac{1\ L}{0.25mol} = 0.775\ L\ HNO_3$

Some of you may look at this and be confused by the single string of dimensional analysis. Perhaps you would prefer to think about solving the problem in three parts as shown below:

$$0.38\ \frac{mol}{L}(M)\ x\ \ 0.245 L\ Na_2CO_3 = 0.0931\ mol\ Na_2CO_3;\quad 0.0931\ mol\ Na_2CO_3\ x\ \ \frac{2\ mol\ HNO_3}{1\ mol\ Na_2CO_3} = 1.862\ mol\ Na_2CO_3$$

$$Molairty = \frac{moles}{liter} \qquad 0.25\ M = \frac{0.1862\ mol}{x},\quad x = 0.775\ L\ HNO_3$$

$$Na_2S_2O_{3(aq)} + 4NaOCl_{(aq)} + 2NaOH_{(aq)} \rightarrow 2Na_2SO_{4(aq)} + 4NaCl_{(aq)} + H_2O_{(L)}$$

17. Answer the following questions about the balanced redox equation shown above.

a. $0.500M\ x\ 0.250\ L = 0.125\ mol\ Na_2S_2O_3$ $\qquad \frac{0.125\ mol\ Na_2S_2O_3}{1} = 0.125\ Na_2S_2O_3$

$2.00M\ x\ 0.150\ L = 0.300\ mol\ NOCl$ $\qquad \frac{0.300\ mol\ NOCl}{4} = 0.075\ Na_2S_2O_3$

$0.60M\ x\ 0.175\ L = 0.105\ mol\ NaOH$ $\qquad \frac{0.105\ mol\ NaOHO}{2} = 0.0525\ Na_2S_2O_3$

Thus NaOH is limiting because from NaOH, $Na_2S_2O_3$ was the smallest amount of moles that can be produced.

b. 0.105 mol NaOH x $\frac{1\ mol\ H_2O}{2\ mol\ NaOH}$ = 0.210 mol H_2O

c. $S_2O_3^{2-}{}_{(aq)} + 4OCl^-{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow 2SO_4^{2-}{}_{(aq)} + 4Cl^-{}_{(aq)} + H_2O_{(L)}$

Note that the sodium spectator ions drop out of the overall equation.

In doing mathematical problems in Chemistry, it is highly recommended to write the formula that you use. There are a lot of topics in Chemistry and a lot of formula. To start a problem, it is best to write the equation that you use to justify answer. If a problem isn't justified well enough no credit will be given. Not only during the course but also on the AP exam.

Solutions

This is the most common method of reporting concentration used in AP chemistry.

Molarity is the number of moles of solute per liter of solution. $\boldsymbol{Molairty\ (M) = \frac{Moles\ of\ solute}{Litere\ of\ Solution}}$

When a more concentrated solution is diluted, the moles of the solute will be the same before and after the dilution. This gives rise to the dilution equation, which is just a variation of the molarity equation. $\mathbf{M_1V_1 = M_2V_2}$

Sample Problems

18. What is the molarity of a solution that contains 6.57 g of magnesium chloride in 250. mL of solution?

19. Given 25.0 mL of a 0.05 M of aluminum sulfate solution.
    a. How many millimoles of aluminum sulfate does this solution contain?

    b. How many millimoles of sulfate does this solution contain?

20. If 38.0 mL of a 6.0 M HCl solution are diluted to a final volume of 250 mL, what is the final concentration?

Gases

There are 4 properties that affect gases: pressure, volume, temperature and moles.
Pressure and volume are inversely related while pressure and temperature are directly related. You should know the relationship between these 4 properties and if they are directly or indirectly related. The easiest way to tell is using the ideal gas law.

The ideal gas law is the most common gas law used in AP Chemistry. The equation is **PV= nRT**. This equation uses all 4 properties of a gas with the universal gas constant. The value of the universal gas constant can change depending on what units it has. Most of the time is it **0.08206 L atom mol^{-1} K^{-1}** but it can be **8.314 J mol^{-1} K^{-1}** and **62.36 L torr mol^{-1} K^{-1}**.

Standard temperature and pressure (**STP**) is also used in AP Chemistry which represent temperature at **273.15K** and **1.0 atm**. The volume of 1.00 mole at STP is **22.4 L mol^{-1}**.

21. How many moles are in a 49.5 L vessel at 298K and a pressure of 1.15 atm?

22. What is the temperature in degree Celsius of 1.15 grams of O_2 in a 315 mL container at 78.6 kPa?

ANSWER

18. What is the molarity of a solution that contains 6.57 g of magnesium chloride in 250. mL of solution?

- *First you need to be able to write out the chemical formula for magnesium chloride, and calculate the molar mass.*
  - $MgCl_2$ $24.31 + 2 \times 35.45 = 95.21$ g/mol
- *Next, convert the mass of magnesium chloride to moles.* $6.57\ g\ MgCl_2\ x \frac{1\ mol\ MgCl_2}{95.21\ g\ MgCl_2} = 0.0690\ mol\ MgCl_2$
- *Next apply the molarity equation.* $\frac{0.069\ mol}{0.25\ L} = \mathbf{0.276M}$

Hey look! Molarity which is moles per liter, is also millimoles per milliliter!!

$$\frac{5\ mol}{1L} = \frac{1000\ millimol}{1\ mol}\ x\ \frac{1\ L}{1000\ mL}\ x\ \frac{5\ millimol}{1\ mL}$$

19. Given 25.0 mL of a 0.05 M of aluminum sulfate solution

a. How many millimoles of aluminum sulfate does this solution contain?

Moles = M x V $0.05M$ x 25mL = 1.25 millimol

b. How many millimoles of sulfate does this solution contain?

To answer part (b) you need to write out the chemical formula for aluminum sulfate. $Al_2(SO_4)_3$

Thus you can see there are three sulfate ions per aluminum sulfate.

$$1.25\ mmol\ Al_2(SO_4)_3\ x \frac{3\ mol\ SO_4^{2-}\ ions}{1\ mol\ Al_2(SO_4)_3} = \mathbf{3.75\ mmol\ SO_4^{2-}\ ions}$$

20. If 38.0 mL of a 6.0 M HCl solution are diluted to a final volume of 250 mL, what is the final concentration?

To answer simply apply the dilution equation; $M_1V_1 = M_2V_2$

$M_1V_1 = M_2V_2$, $M_2 = \frac{6M\ x\ 38mL}{250\ mL}$, **$M_2 = 0.91M$**

21. How many moles of oxygen are in a 49.5 L vessel at 298K and a pressure of 1.15 atm?

To answer this, you will use the ideal gas law. PV=nRT

P = 1.15 atm

V = 49.5 L

T = 298K

PV = nRT

$$n = \frac{PV}{RT} = \frac{(1.15\ atm)(49.5\ L)}{(0.08206\ L\ atm\ mol^{-1}\ K^{-1})(298K)} = 2.33\ mol$$

22. What is the temperature in degree Celsius of 1.15 grams of O_2 in a 315 mL container at 78.6 kPa?

To answer this, you will use the ideal gas law again but you need to convert to the correct units before plugging into the equation. PV=nRT

$P = 78.6\ kPa\ x\ \frac{1\ atm}{101.325\ kPa} = 0.776\ atm$ $V = 315\ mL\ x\ \frac{1\ L}{1000\ mL} = 0.315\ L$

$1.15\ grams\ O_2 = \frac{1\ mol\ O_2}{32\ grams\ O_2} = 0.0360\ mol\ O_2$

$$T = \frac{PV}{nR} = \frac{(0.776\ atm)(0.315\ L)}{(0.0360\ mol)(0.08206\ L\ atm\ mol^{-1}\ K^{-1})} = 82.9K$$

$T^oC = T_K + 273.15$

$T^oC = 82.9 + 273.15 =$ ***356.0°C***