Name _____ **Date** _____ **Period** _____

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AP Chemistry Unit 4 Study Guide

Chemical Reactions (Topics 4.1 to 4.9)

Show all work with units and correct significant figures. When a question asks you to explain, make a claim and support it with a particle-level reason.

Constants	$N_A = 6.022 \times 10^{23}\ mol^{-1}$	R = 0.08206 L·atm/(mol·K)	K = °C + 273	1 atm = 760 torr
Equations	moles = mass ÷ molar mass	molarity = mol solute ÷ L solution	PV = nRT	% yield = (actual ÷ theoretical) × 100

Part 1. Physical and Chemical Changes (Topics 4.1 and 4.4)

1. For each process, decide whether it is a physical change or a chemical change, and give the evidence or particle-level reason.

Process	Physical or chemical?	Evidence or reason
Dry ice, $CO_2(s)$, turns directly into a gas		
A magnesium ribbon burns with a bright white light		
Mixing clear NaCl(aq) and $AgNO_3(aq)$ forms a white solid		
Sugar dissolves in water		
An iron nail slowly turns into orange-brown rust		

2. A student claims, "Boiling water is a chemical change because bubbles of gas form." Do you agree or disagree? Explain in terms of the bonds or forces that are overcome.

3. Dissolving NaCl(s) in water can be argued to be either a physical or a chemical process.

(a) Give one argument that it is a physical process.

(b) Give one argument that it is a chemical process.

Part 2. Net Ionic Equations (Topic 4.2)

4. Clear solutions of lead(II) nitrate, $Pb(NO_3)_2(aq)$, and potassium iodide, KI(aq), are mixed, and a bright yellow solid forms. (All potassium and nitrate salts are soluble.)

(a) Write the balanced molecular equation, with states.

(b) Write the complete ionic equation.

(c) Write the net ionic equation and name the spectator ions.

5. Write the net ionic equation for each reaction. Remember that weak acids and solids are written as intact formulas, not as ions.

(a) $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

(b) $HC_2H_3O_2(aq) + NaOH(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(l)$ (acetic acid is a weak acid)

(c) $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

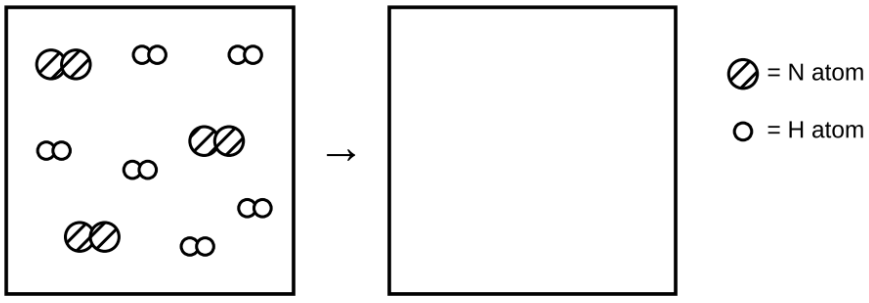
6. Physical changes can be shown with balanced equations too. Write a balanced equation, with states, for each change.

(a) Solid iodine sublimes.

(b) Solid ammonium nitrate dissolves in water.

Part 3. Representations of Reactions (Topic 4.3)

7. Nitrogen and hydrogen react to form ammonia: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$. The left box shows a reaction mixture before any reaction occurs.

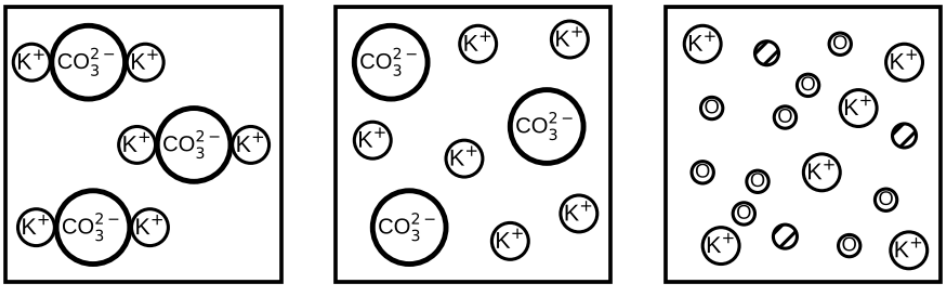


(a) In the right box, draw the particles present after the reaction goes to completion.

(b) Identify the limiting reactant. Justify your answer using the diagram.

8. Which box best represents $K_2CO_3(aq)$? Circle one: **A** **B** **C**. Then explain what is wrong with each of the other two boxes.

Water molecules are not shown. Hatched small circles in C are carbon atoms.



A **B** **C**

Part 4. Stoichiometry (Topic 4.5)

9. Aluminum reacts with chlorine gas: $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$. A student reacts 10.0 g of Al with 35.0 g of Cl_2. (Molar masses: Al 26.98, Cl_2 70.90, $AlCl_3$ 133.33 g/mol)

(a) Identify the limiting reactant. Show your work.

(b) Calculate the theoretical yield of $AlCl_3$ in grams.

(c) What mass of the excess reactant remains?

(d) The student actually collects 38.2 g of $AlCl_3$. Calculate the percent yield.

10. If the student had used 20.0 g of Al with the same 35.0 g of Cl_2, the mass of $AlCl_3$ formed would (circle one) **increase decrease stay the same**. Explain.

11. Potassium chlorate decomposes when heated: $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$. What volume of O_2 forms at 1.00 atm and 298 K when 4.90 g of $KClO_3$ (122.55 g/mol) decomposes completely?

12. Silver nitrate solution is added to 25.0 mL of 0.150 M $CaCl_2(aq)$. The net ionic equation is $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$.

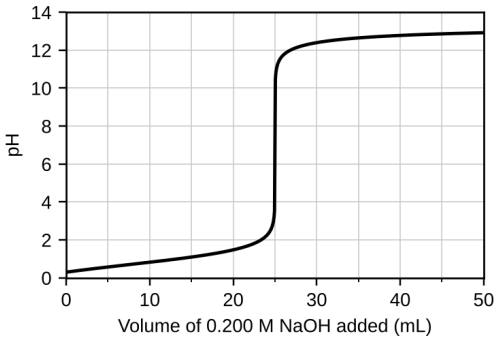
(a) What volume of 0.250 M $AgNO_3$ is needed to precipitate all of the chloride ions?

(b) What mass of AgCl (143.32 g/mol) forms?

Part 5. Introduction to Titration (Topic 4.6)

13. A 20.0 mL sample of HCl(aq) is titrated with 0.100 M NaOH. The indicator changes color when 24.6 mL of NaOH has been added. Calculate the concentration of the HCl.

14. The graph shows the titration of a 10.0 mL sample of HCl(aq) with 0.200 M NaOH.



(a) Circle the equivalence point on the graph and estimate the volume of NaOH added there.

(b) Calculate the concentration of the HCl.

(c) Explain the difference between the equivalence point and the endpoint.

15. Before a titration, a student rinses the buret with distilled water but not with the NaOH solution, so a few drops of water dilute the NaOH. Will the calculated concentration of the acid be too high, too low, or unaffected? Explain.

Part 6. Types of Chemical Reactions (Topic 4.7)

16. Classify each reaction as **precipitation**, **acid-base**, or **redox**, and give the evidence.

Reaction	Type	Evidence
$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$		
$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$		
$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$		
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$		

17. Write the balanced equation for the complete combustion of propane, $C_3H_8(g)$. Then explain why combustion is classified as a redox reaction.

18. Using only the rule that all sodium, potassium, ammonium, and nitrate salts are soluble, circle every compound that *must* be soluble in water:

KBr **NH_4Cl** **$BaSO_4$** **$Pb(NO_3)_2$** **AgCl** **Na_3PO_4**

19. Write **T** or **F** for each statement. Rewrite each false statement so it is true.

Statement	T or F	Correction (if false)
The complete combustion of a hydrocarbon is an acid-base reaction.		
In a precipitation reaction, the oxidation numbers of the ions change.		
In a redox reaction, electrons move from the species oxidized to the species reduced.		

Part 7. Acid-Base Reactions (Topic 4.8)

20. For each reaction, identify the Brønsted-Lowry acid, base, conjugate acid, and conjugate base.

Reaction	Acid	Base	Conj. acid	Conj. base
$HF(aq) + H_2O(l) \rightleftharpoons F^-(aq) + H_3O^+(aq)$				
$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$				
$HSO_4^-(aq) + CO_3^{2-}(aq) \rightleftharpoons SO_4^{2-}(aq) + HCO_3^-(aq)$				

21. Use the first two reactions in the table above to explain why water is described as able to act as both an acid and a base.

Part 8. Oxidation-Reduction (Redox) Reactions (Topics 4.7 and 4.9)

22. Assign the oxidation number of the named atom in each species.

Cr in $Cr_2O_7^{2-}$	S in SO_4^{2-}	N in NH_4^+	Mn in MnO_4^-	O in H_2O_2

23. Consider $2Fe^{3+}(aq) + Sn^{2+}(aq) \rightarrow 2Fe^{2+}(aq) + Sn^{4+}(aq)$.

(a) Which species is oxidized and which is reduced? Explain.

(b) Write the oxidation and reduction half-reactions. How many electrons are transferred in the balanced reaction?

24. Use half-reactions to balance this reaction in acidic solution: $MnO_4^-(aq) + Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + Fe^{3+}(aq)$

25. Using the balanced equation from the previous question, a 25.00 mL sample of $Fe^{2+}(aq)$ requires 18.40 mL of 0.0200 M $KMnO_4$ to reach the endpoint (the first lasting pink color). Calculate $[Fe^{2+}]$.

26. A student writes $Cu(s) + Ag^+(aq) \rightarrow Cu^{2+}(aq) + Ag(s)$ and says it is balanced because the atoms balance. Explain the error and write the correctly balanced equation.