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

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AP Chemistry Unit 3 Study Guide

Properties of Substances and Mixtures (Topics 3.1 to 3.13)

Show all work with units and correct significant figures. In explanations, name the specific force for **both** substances, not just "stronger" or "weaker."

Constants	R = 0.08206 L·atm/(mol·K)	R = 62.36 L·torr/(mol·K)	1 atm = 760 torr = 760 mmHg	STP: 273 K and 1.00 atm 1 mol gas = 22.4 L
	$h = 6.626 \times 10^{-34}$ J·s	$c = 3.00 \times 10^{8}$ m/s	$N_A = 6.022 \times 10^{23}$ mol^{-1}	K = °C + 273
Equations	PV = nRT	$P_A = P_{total} \times X_A$	$P_{total} = P_A + P_B + ...$	$KE = \frac{1}{2}mv^2$
	M = mol solute ÷ L solution	$M_1V_1 = M_2V_2$	$c = \lambda\nu$ $E = h\nu$	$A = \varepsilon bc$

Part 1. Intermolecular Forces (Topic 3.1)

1. Complete the table. IMF choices: London dispersion forces (LDF), dipole-dipole, hydrogen bonding.

Substance	Polar or nonpolar?	All IMFs present between its molecules	H-bonds with itself? (Y/N)
Kr			
H_2S			
CH_3NH_2			
CCl_4			
H_2CO (formaldehyde)			

2. Account for each difference using the types and strengths of IMFs. Discuss **both** substances.

(a) Propane, C_3H_8 (44 g/mol), boils at 231 K. Acetaldehyde, CH_3CHO (44 g/mol), boils at 294 K.

(b) Nonpolar CCl_4 (bp 350 K) boils at a higher temperature than polar CH_2Cl_2 (bp 313 K).

3. A student claims, "When liquid bromine, Br_2, boils, the Br–Br bonds break and Br atoms form." Do you agree or disagree? Justify your answer.

Part 2. Properties of Solids (Topic 3.2)

4. Classify each solid and describe what holds it together.

Solid	Type of solid	Particles that make up the solid	Forces holding particles together
MgO			
SiC			
Cu			
$C_{12}H_{22}O_{11}$ (sucrose)			

5. Rank KBr, NaF, and MgO from **lowest** to **highest** melting point. Justify using Coulomb's law.

6. Explain each observation at the particle level.

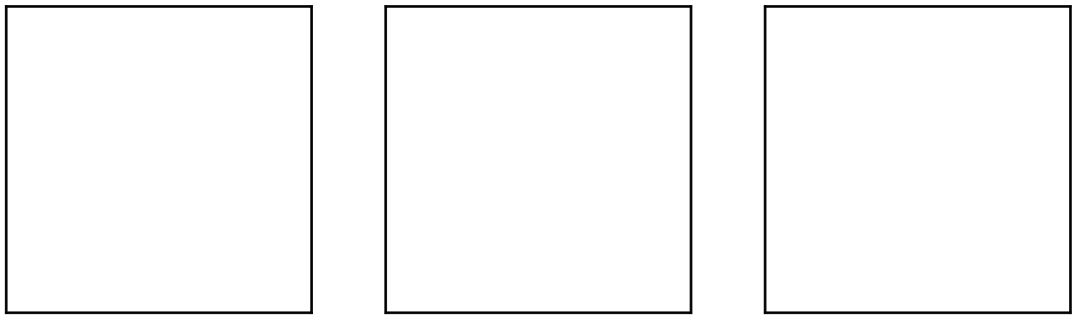
(a) An ionic crystal shatters when struck, but a piece of copper bends.

(b) Graphite is soft, but diamond is very hard. Steel (C atoms in Fe) is less malleable than pure Fe.

Part 3. Solids, Liquids, and Gases and Properties of Liquids (Topics 3.2 and 3.3)

7. Draw about 8 molecules (as small circles) in each box to show the same substance as a solid, liquid, and gas. Then explain why the solid and liquid have similar molar volumes but the gas does not.

Solid **Liquid** **Gas**



8. At 25 °C, the vapor pressure of diethyl ether is 530 torr and the vapor pressure of water is 24 torr. Circle the liquid that fits each description, then answer the question below the table.

Property	Circle one	Property	Circle one
Stronger IMFs	Ether / Water	Higher viscosity	Ether / Water
Higher boiling point	Ether / Water	Larger heat of vaporization	Ether / Water
Evaporates faster	Ether / Water	Feels colder on skin	Ether / Water

Explain why the liquid you chose for "feels colder on skin" cools the skin more.

9. In a narrow glass tube, water rises and forms a concave (U-shaped) meniscus. Mercury drops and forms a convex meniscus. Explain using cohesive and adhesive forces.

10. A sealed flask holds a liquid and its vapor at constant temperature. Write T or F. Correct any false statement.

(a) Once the pressure is constant, evaporation and condensation stop.

(b) Raising the temperature increases the vapor pressure.

(c) Doubling the flask volume (liquid still present) permanently lowers the vapor pressure.

Part 4. Gases: Ideal Gas Law, Kinetic Molecular Theory, Real Gases (Topics 3.4 to 3.6)

11. Zinc reacts with acid: $Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$. A student collects 0.325 L of H_2 over water at 25 °C and a total pressure of 748 torr. The vapor pressure of water at 25 °C is 23.8 torr.

(a) Calculate the partial pressure of the dry H_2.

(b) Calculate the moles of H_2 collected.

(c) Calculate the mass of Zn that reacted.

(d) Calculate the volume of the dry H_2 at STP.

12. A rigid container holds 2.0 mol N_2, 3.0 mol O_2, and 1.0 mol He at a total pressure of 3.0 atm.

(a) Calculate the partial pressure of O_2.

(b) 1.0 mol Ar is added at constant T. Does P_{He} increase, decrease, or stay the same? Explain.

13. For He, N_2, CO_2, and SO_2, all at the same temperature and pressure, write the gas that fits.

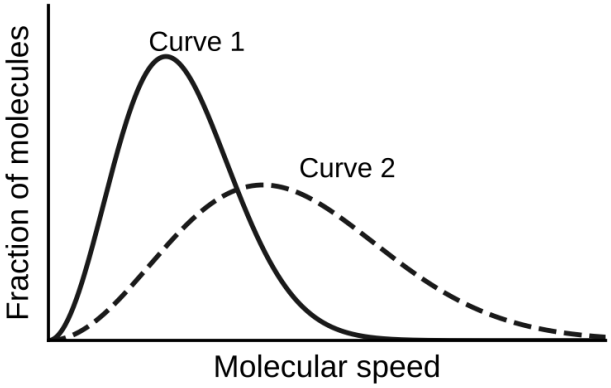
Description	Gas
Highest average kinetic energy	
Highest average speed	
Slowest rate of effusion	
Weakest IMFs	
Greatest deviation from ideal behavior	

14. Real gases deviate from ideal behavior. Explain each observation at the particle level.

(a) At very high pressure, the measured volume is *greater* than the ideal volume.

(b) At low temperature (near condensation), the measured pressure is *less* than ideal.

15. The graph shows the speed distribution of N_2 molecules at two temperatures.

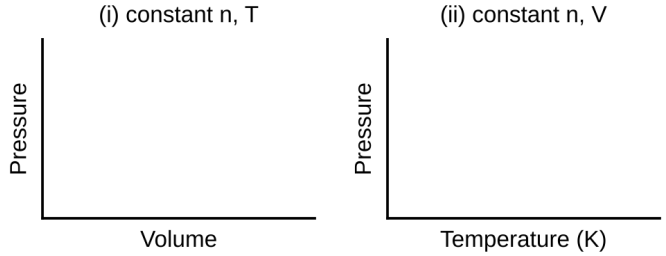


(a) Which curve is at the higher temperature? Justify.

(b) Why is the area under both curves the same?

(c) If the curves instead showed He and Ar at the same T, which curve is He? Why?

16. Sketch each relationship for an ideal gas.



Part 5. Solutions and Representations of Solutions (Topics 3.7 and 3.8)

17. 2.84 g of Na_2SO_4 (142.04 g/mol) is dissolved in water to make 250.0 mL of solution.

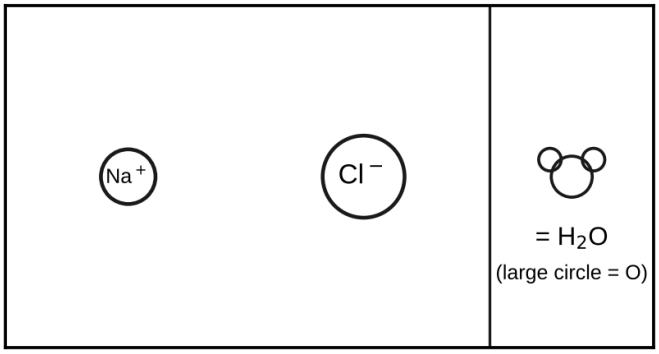
(a) Calculate the molarity of Na_2SO_4.

(b) Calculate $[Na^+]$ and the number of Na^+ ions.

19. How many mL of 12.0 M HCl are needed to make 250. mL of 1.50 M HCl? How much water is added (assume volumes are additive)?

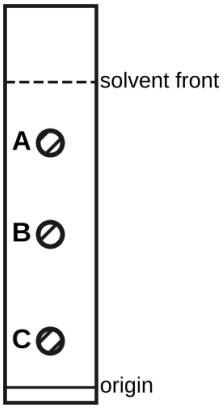
18. Describe how to prepare 500.0 mL of 0.150 M $CuSO_4$ (159.61 g/mol) from the solid. Why is "dissolve the solid in 500.0 mL of water" incorrect?

20. Draw 3 water molecules around each ion to show how water orients around the ions in NaCl(aq).



Part 6. Separation of Solutions and Mixtures (Topic 3.9)

21. A mixture is separated by thin-layer chromatography on silica (polar stationary phase) using 20% ethyl acetate in hexane (mostly nonpolar mobile phase). Distances from the origin: front 8.0 cm, A 6.4 cm, B 4.0 cm, C 1.2 cm.

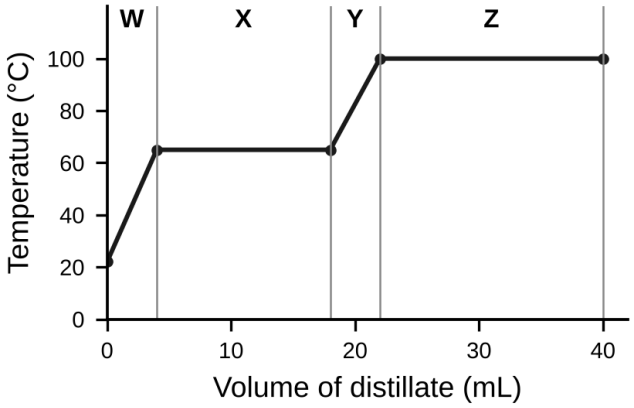


(a) Which component is most polar? Explain.

(b) Calculate R_f for B.

(c) To make all spots travel *farther*, should the percentage of ethyl acetate be increased or decreased? Explain.

22. A mixture of methanol, CH_3OH, and water is separated by fractional distillation.



(a) Which substance is collected in range X? Explain using IMFs.

(b) Why can't this mixture be separated by filtration?

Part 7. Solubility (Topic 3.10)

23. Circle the solvent each substance dissolves in better and name the key solute-solvent attraction.

Solute	Water or hexane?	Key attraction
KBr	Water / Hexane	
C_8H_{18}	Water / Hexane	
I_2	Water / Hexane	
CH_3COOH	Water / Hexane	

24. Acetone, CH_3COCH_3, cannot hydrogen bond with itself, yet it mixes with water in all proportions. Explain.

25. Nonpolar N_2 dissolves slightly in water. What attraction allows this?

Part 8. Spectroscopy, Photons, and the Beer-Lambert Law (Topics 3.11 to 3.13)

26. Complete the table.

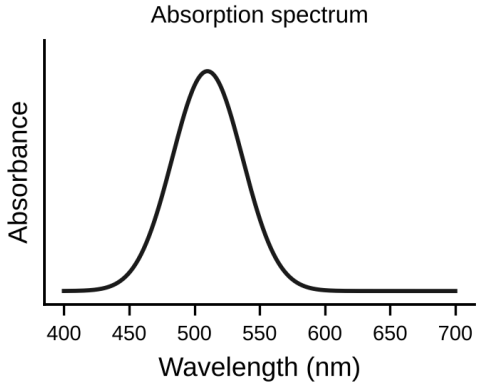
Radiation absorbed	Type of transition
Microwave	
Infrared (IR)	
Ultraviolet/visible	

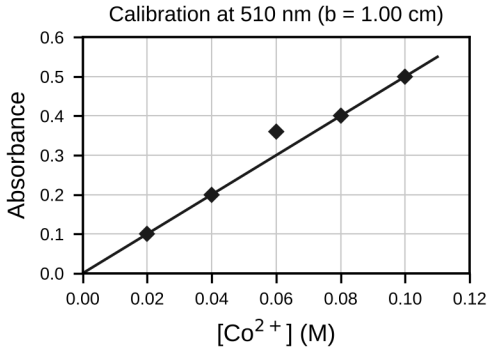
27. Blue light has a wavelength of 450. nm.

(a) Calculate its frequency and the energy of one photon.

(b) *No calculator:* estimate E for a photon with $\nu = 2 \times 10^{15}\ s^{-1}$.

28. A student uses a spectrophotometer to find the mass percent of $Co(NO_3)_2$ (182.94 g/mol) in an impure 1.50 g sample. The impurity is colorless.





(a) Which wavelength should be used? Why?

(b) Determine ε from the line (b = 1.00 cm).

(c) The 0.060 M point is above the line. Give one likely cause.

(d) The sample is dissolved to make 100.0 mL of solution, and its absorbance is 0.320. Calculate the mass percent of $Co(NO_3)_2$.

(e) Water droplets were left in the cuvette before adding the sample. Is the calculated mass percent too high or too low? Explain.