AP Chemistry Unit 3 Practice Test
Solids, Liquids, Gases and Solutions

Name Key
Date _____ Block ____

1. A real gas would act most ideal at
(A) 1 atm and 273 K
(B) 10 atm and 547 K
(C) 10 atm and 273 K
(D) 0.5 atm and 546 K
(E) 0.5 atm and 273 K

2. Zinc reacts with aqueous sulfuric acid to form hydrogen gas:
$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$
In an experiment, 201 mL of wet H_2 is collected over water at 27°C and a barometric pressure of 733 torr. The vapor pressure of water at 27°C is 26.74 torr. The partial pressure of hydrogen in this experiment is _____ atm.
(A) 0.929
(B) 760
(C) 706
(D) 1.00
(E) 0.964
706.26 torr → atm
733 − 26.74

3. A mixture of gases contains 1.5 moles of oxygen, 3.0 moles of nitrogen, and 0.5 mole of water vapor. If the total pressure is 700 mmHg, what is the partial pressure of the nitrogen gas?
(A) 70 mmHg
(B) 210 mmHg
(C) 280 mmHg
(D) 350 mmHg
(E) 420 mmHg
$\frac{3}{5} \times 700$

4. Equal numbers of moles of $CO_2(g)$, $N_2(g)$, and $NH_3(g)$ are placed in a sealed vessel at room temperature. If the vessel has a pinhole-size leak, which of the following will be true after some of the gas mixture has effused?
(44, 28, 17)
I. The mole fraction of CO_2 in the sample will increase.
II. The N_2 will effuse the fastest since it is the lightest. ✗
III. All gases will effuse at the same rate since the temperature is held constant. ✗
(A) I only
(B) III only
(C) I and II
(D) II and III
(E) I, II, and III

5. A sample of oxygen gas was found to effuse at a rate equal to two times that of an unknown gas. The molecular weight of the unknown gas is _____ g/mol.
(A) 128
(B) 8
(C) 16
(D) 64
$\frac{2}{1} = \sqrt{\frac{x}{32}}$
$4 = \frac{x}{32}$

each = .5 mol

6. Two flexible containers for gases are at the same temperature and pressure. One holds 14 g of nitrogen and the other holds 22 g of carbon dioxide. Which of the following statements about these gas samples is true?
(A) The volume of the carbon dioxide container is the same as the volume of the nitrogen container.
(B) The number of molecules in the carbon dioxide container is greater than the number of molecules in the nitrogen container.
(C) The density of the carbon dioxide sample is the same as that of the nitrogen sample.
(D) The average kinetic energy of the carbon dioxide molecules is greater than the average kinetic energy of the nitrogen molecules.
(E) The average speed of the carbon dioxide molecules is greater than the average speed of the nitrogen molecules.

7. A hydrocarbon gas with the empirical formula CH_2 has a density of 1.3 g/L at 0°C and 1.00 atm. A possible formula for the hydrocarbon is:
(A) CH_2
(B) C_2H_4
(C) C_3H_6
(D) C_4H_8
(E) C_5H_{10}
STP
$\frac{1.3g}{L} \times \frac{22.4L}{mol} \approx 29\ g/mol$

8. A 0.33 mole sample of $CaCO_3(s)$ is placed in a 1 L evacuated flask, which is then sealed and heated. The $CaCO_3(s)$ decomposes completely according to the balanced equation below. The total pressure in the flask, measured at 300 K is closest to which of the following? (The gas constant, R = 0.082 L atm/mol K)
$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
(A) 2.0 atm
(B) 4.1 atm
(C) 8.1 atm
(D) 16 atm
(E) 18 atm
$PV = nRT$
$P \times 1 = .33 \times .082 \times 300$
$P \approx .082 \times 100$

9. When a sample of carbon dioxide gas in a closed container of constant volume at 0.5 atm and 200 K is heated until its temperature reaches 400 K, its new pressure is closest to
(A) 0.25 atm
(B) 0.50 atm
(C) 1.0 atm
(D) 1.5 atm
(E) 2.0 atm
$\frac{.5}{200} = \frac{P_2}{400}$

10. The pressure of 4.0 L of an ideal gas in a flexible container is decreased to one-third of its original pressure and its absolute temperature is decreased by one-half. The volume then is
(A) 1.0 L
(B) 4.0 L
(C) 6.0 L
(D) 8.0 L
(E) 24 L
$\frac{P \times 4}{T} = \frac{\frac{1}{3}P \times V}{\frac{1}{2}T}$
$4 = \frac{2}{3}V$
$V = 6$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

11. A given mass of a gas occupies 5.00 L at 65 °C and 480 mmHg. What is the volume of the gas at 630 mmHg and 85 °C?

a. $5.00 \times \frac{65}{85} \times \frac{480}{630}$

b. $5.00 \times \frac{338}{358} \times \frac{480}{630}$

c. $5.00 \times \frac{358}{338} \times \frac{480}{630}$

d. $5.00 \times \frac{358}{338} \times \frac{630}{480}$

e. $5.00 \times \frac{338}{358} \times \frac{630}{480}$

$\frac{480 \times 5}{65+273} = \frac{630 \times V}{85+273}$

$V = \frac{480 \times 5 \times 358}{338 \times 630}$

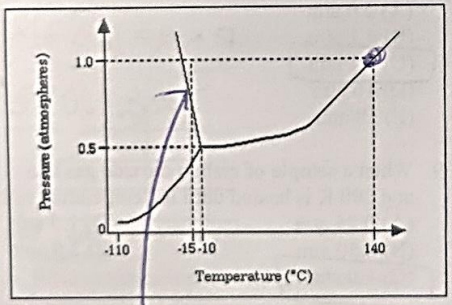
12. A gas sample is confined in a 5-liter container. Which of the following will occur if the temperature of the container is increased?

I. The kinetic energy of the gas will increase. ✓
II. The pressure of the gas will increase ✓
III. The density of the gas will increase. ✗

(A) I only
(B) II only
(C) I and II only
(D) I and III only
(E) I, II, and III

@ 1 atm

13. The normal boiling point of the substance represented by the phase diagram is
(A) -15°C
(B) -10°C
(C) 140°C
(D) Greater than 140°C



negative slope
∴ solid less dense than liquid

14. For the substance represented in the diagram, which of the phases is most dense and which is least dense at -15°C

	Most Dense	Least Dense
(A)	Solid	Gas
(B)	Solid	Liquid
(C)	Liquid	Solid
(D)	Liquid	Gas

15. Based on the data in the table, which of the following liquid substances has the weakest intermolecular forces?
(A) $C_6H_6(l)$
(B) $C_2H_5OH(l)$
(C) $CH_3OH(l)$
(D) $C_2H_6O_2(l)$

Substance	Equilibrium Vapor Pressure at 20°C (torr)
$C_6H_6(l)$	75
$C_2H_5OH(l)$	44
$CH_3OH(l)$	92
$C_2H_6O_2(l)$	0.06

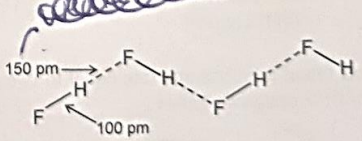
Highest VP = weakest IMFs

16. Based on the data in the table, which of the following correctly predicts the relative strength of the attraction of Zn^{2+}, Ca^{2+}, and Ba^{2+} ions to water molecules in a solution, from strongest to weakest, and provides the correct reason?
(A) $Zn^{2+} > Ca^{2+} > Ba^{2+}$ because the smaller ions have a stronger coulombic attraction to water.
(B) $Zn^{2+} > Ca^{2+} > Ba^{2+}$ because the smaller ions are more electronegative.
(C) $Ba^{2+} > Ca^{2+} > Zn^{2+}$ because the larger ions are more polarizable.
(D) $Ba^{2+} > Ca^{2+} > Zn^{2+}$ because the larger ions are less electronegative.

Ion	Ionic Radius (pm)
Zn^{2+}	74
Ca^{2+}	100
Ba^{2+}	135

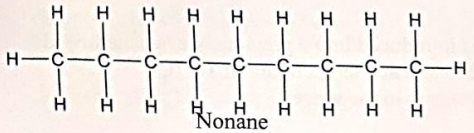
17. Methane (CH_4) and Propane (C_3H_8) gas are each in an identical rigid container at the same temperature and pressure. If the pressure of each gas is slowly increased at constant temperature until condensation occurs, which gas will condense first?
(A) Methane will condense first because it has a smaller molecular size, and it is more polarizable than propane.
(B) Methane will condense first because it has a smaller molecular size, and it is less polarizable than propane.
(C) Propane will condense first because it has a larger molecular size, and it is more polarizable than methane.
(D) Propane will condense first because it has a larger molecular size, and it is less polarizable than methane.

larger = ↑ IMFs = condense first

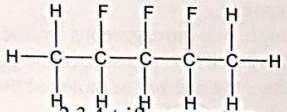


longer length = weaker attraction.

18. The figure above shows that in solid hydrogen fluoride there are two different distances between H atoms and F atoms. Which of the following best accounts for the two different distances?
(A) Accommodation of the necessary bond angles in the formation of the solid
(B) Difference in strength between covalent bonds and intermolecular attractions
(C) Different isotopes of fluorine present in the sample
(D) Uneven repulsions among nonbonding electron pairs



Nonane



2,3,4-trifluoropentane

19. Consider the molecules represented above and the data in the table below.

Compound	Molecular Formula	Molar Mass (g/mol)	Boiling Point (°C)
Nonane	C_9H_{20}	128	151
2,3,4-trifluoropentane	$C_5H_9F_3$	126	89

Nonane and 2,3,4-trifluoropentane have almost identical molar masses, but nonane has a significantly higher boiling point. Which of the following statements best helps to explain this observation? longer chains = ↑ IMFs

(A) The C–F bond is easier to break than the C–H bond.
(B) The C–F bond is more polar than the C–H bond.
(C) The carbon chains are longer in nonane than they are in 2,3,4-trifluoropentane.
(D) The carbon chains are farther apart in a sample of nonane than they are in 2,3,4-trifluoropentane.

20. Which of the following could be the identity of a white crystalline solid that exhibits the following properties?

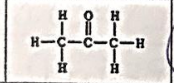
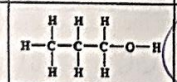
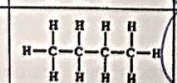
- It melts at 320°C.
- It does not conduct electricity as a solid.
- It conducts electricity in an aqueous solution.

} ionic

(A) $C_6H_{12}O_6(s)$
(B) $NaOH(s)$
(C) $SiO_2(s)$
(D) $Cu(s)$

21. The table shows the structural formulas and molar masses for three different compounds. Which of the following is a list of the compounds in order of increasing boiling points?

(A) Butane < 1-propanol < acetone
(B) Butane < acetone < 1-propanol
(C) 1-propanol < acetone < butane
(D) Acetone = butane < 1-propanol

Name	Structural Formula	Molar Mass (g/mol)
Acetone		58.1
1-propanol		60.1
Butane		58.1

polar
polar
nonpolar

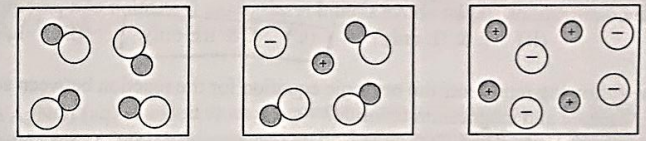
22. Which of the following best explains why more energy is required to boil a substance than to melt it?

(A) Intermolecular attractions are completely overcome during vaporization
(B) Intermolecular attractions in the solid phase are weaker than in the liquid phase
(C) Electron clouds of methane molecules are less polarizable at lower temperatures
(D) Vaporization involves a large increase in temperature

23. Which of the following aqueous solutions will have the highest boiling point? i × m

(A) 0.10 m $SrSO_4$ 2 × .1
(B) 0.20 m $C_6H_{12}O_6$ 1 × .2
(C) 0.25 m $C_{12}H_{22}O_{11}$ 1 × .25
(D) 0.10 m Na_2SO_4 3 × .1
(E) 0.10 m NaCl 2 × .1

The diagrams below represent aqueous solutions of substances AB, RS, and XY. Water molecules are not shown for simplicity.



XY AB RS

24. Which of the following represents the correct classification of these three substances?

	strong electrolyte	weak electrolyte	nonelectrolyte
(A)	AB	RS	XY
(B)	RS	XY	AB
(C)	XY	RS	AB
(D)	RS	AB	XY

25. Both sodium hydroxide and methanol are soluble in water. Which of the following choices best represents the behavior of these two solutes in aqueous solution?

(A)	$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$	$CH_3OH(l) \rightarrow CH_3OH(aq)$
(B)	$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$	$CH_3OH(l) \rightarrow CH_3^+(aq) + OH^-(aq)$
(C)	$NaOH(s) \rightarrow NaOH(aq)$	$CH_3OH(l) \rightarrow CH_3OH(aq)$
(D)	$NaOH(s) \rightarrow NaOH(aq)$	$CH_3OH(l) \rightarrow CH_3^+(aq) + OH^-(aq)$

26. Solid NH_4Br is soluble in water. Which of the following choices best represents NH_4Br as a solute in aqueous solution?

(A) $NH_4Br(s) \rightarrow NH_4Br(aq)$
(B) $NH_4Br(s) \rightarrow NH_4^+(aq) + Br^-(aq)$
(C) $NH_4Br(s) \rightarrow NH_3(aq) + H^+(aq) + Br^-(aq)$
(D) $NH_4Br(s) \rightarrow N^{3-}(aq) + 4\,H^+(aq) + Br^-(aq)$

AgCl = insoluble in water

27. Which of the statements below best explains the behavior of silver chloride in water?
I. There is a strong attraction between the solute ions and the solvent molecules.
II. There is a strong attraction between the solute molecules and the solvent molecules.
III. There is a strong attraction between silver ions and chloride ions.
(A) I. only (B) II. only (C) III. only (D) I. & III. only

28. Which of the following represents the most accurate summary of what occurs when solutions of copper(II) sulfate and iron(II) nitrate are mixed together?
(A) No precipitate is formed.
(B) A precipitate of copper(II) nitrate is formed.
(C) A precipitate of iron(II) sulfate is formed.
(D) Both copper(II) sulfate and iron(II) nitrate are insoluble, so no reaction occurs.

$CuSO_4 + Fe(NO_3)_2 \rightarrow FeSO_4 + Cu(NO_3)_2$

I. mixing solutions of lead(II) nitrate and potassium sulfate ✓ → $PbSO_4 + KNO_3$
II. mixing solutions of calcium chloride and lithium hydroxide ✗ → $LiCl_2 + Ca(OH)_2$
III. mixing solutions of barium bromide and sodium carbonate ✓ → $NaBr + BaCO_3$

29. Which of the combinations shown above should result in the formation of a precipitate?
(A) I. only (B) I. & II. only (C) I. & III. only (D) I., II. & III.

30. Which of the following represents the net ionic equation for the reaction between solutions of sodium phosphate and magnesium chloride?
(A) $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(s)$
(B) $3\ Na^+(aq) + PO_4^{3-}(aq) \rightarrow Na_3PO_4(s)$
(C) $Mg^{2+}(aq) + 2\ Cl^-(aq) \rightarrow MgCl_2(s)$
(D) $3\ Mg^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Mg_3(PO_4)_2(s)$

$Na_3PO_4 + MgCl_2 \rightarrow Mg_3(PO_4)_2 + NaCl$
soluble soluble insoluble soluble

1d) $C_xH_y + O_2 \rightarrow CO_2 + H_2O$

	.2	.1	.6	.8
divide by .1	1	5	3	4

$1\ C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

Free Response

1. A sample of a pure, gaseous hydrocarbon is introduced into a previously evacuated rigid 1.00 L vessel. The pressure of the gas is 0.200 atm at a temperature of 127°C.

(a) Calculate the number of moles of the hydrocarbon in the vessel.

$PV = nRT$

$(0.200\ atm)(1.00\ L) = n\ (0.0821)(127+273)$

$n = 0.00609\ mol$

(b) $O_2(g)$ is introduced into the same vessel containing the hydrocarbon. After the addition of the $O_2(g)$, the total pressure of the gas mixture in the vessel is 1.40 atm at 127°C. Calculate the partial pressure of $O_2(g)$ in the vessel.

$P_{total} = P_{O_2} + P_{HC}$

$1.40 = P_{O_2} + 0.2$

$P_{O_2} = 1.20\ atm$

The mixture of the hydrocarbon and oxygen is sparked so that a complete combustion reaction occurs, producing $CO_2(g)$ and $H_2O(g)$. The partial pressures of these gases at 127°C are 0.600 atm for $CO_2(g)$ and 0.800 atm for $H_2O(g)$. There is $O_2(g)$ remaining in the container after the reaction is complete.

$C_xH_y + O_2 \rightarrow CO_2 + H_2O$

(c) Use the partial pressures of $CO_2(g)$ and $H_2O(g)$ to calculate the partial pressure of the $O_2(g)$ consumed in the combustion.

$n\ CO_2 = \frac{(.6\ atm)(1.0\ L)}{(.0821)(400\ K)} = 0.0183\ mol\ CO_2 \times \frac{1\ mol\ O_2}{1\ mol\ CO_2} = .0183$

$n\ H_2O = \frac{(.8)(1.0\ L)}{(.0821)(400\ K)} = 0.0244\ mol\ H_2O \times \frac{1\ mol\ O_2}{2\ mol\ H_2O} = .0122$

(d) On the basis of your answers above, write the balanced chemical equation for the combustion reaction and determine the formula of the hydrocarbon.

$n\ O_2 = 0.0183 + 0.0122 = 0.0305\ mol$

$P \times (1.0\ L) = (0.0305)(0.0821)(400)$

$P = 1.00\ atm\ O_2$

(e) Calculate the mass of the hydrocarbon that was combusted.

$0.00609\ mol \times \frac{44.11\ g}{1\ mol\ C_3H_8} = 0.269\ g\ C_3H_8$

(f) The hydrocarbon is readily soluble in water. A solution was prepared by mixing 5.00 grams of the hydrocarbon in 100. grams of water. Calculate the freezing point of this solution. The molal freezing point depression constant for water is 1.86 °C/m

$\Delta T_f = i \times K_f \times m$

$= 1 \times 1.86 \times \frac{(5\ g \times \frac{1\ mol}{44.11\ g})}{0.1\ kg}$

$= 2.11°C$

$T_f = 0 - 2.11°C = -2.11°C$

2. Write **balanced** chemical equations for what happens when each of the following substances is dissolved into water.

(a) Solid aluminum nitrate is dissolved in water.

$Al(NO_3)_3(s) \rightarrow Al^{+3}(aq) + 3\ NO_3^{-1}(aq)$

(b) Liquid ethanol (C_2H_5OH) is dissolved into water.

$C_2H_5OH(l) \rightarrow C_2H_5OH(aq)$

3. For each pair of compounds, aqueous solutions of the two compounds are to be mixed together. If a precipitate is formed, write the **balanced** molecular equation and the **balanced** net ionic equation. If no precipitate is formed, write "no reaction." The first one has been done for you as an example.

(a) silver nitrate and sodium chloride

molecular equation: $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

net ionic equation: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

(b) magnesium sulfate and barium chloride

molecular equation: $MgSO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + MgCl_2(aq)$

net ionic equation:

$Ba^{+2}(aq) + SO_4^{-2}(aq) \rightarrow BaSO_4(s)$

(c) lead(II) nitrate and potassium iodide

molecular equation:

$Pb(NO_3)_2(aq) + 2\ KI(aq) \rightarrow 2\ KNO_3(aq) + PbI_2(s)$

net ionic equation:

$Pb^{+2}(aq) + 2\ I^-(aq) \rightarrow PbI_2(s)$

(d) manganese(II) acetate and sodium sulfide

molecular equation:

$Mn(CH_3COO)_2(aq) + Na_2S(aq) \rightarrow 2NaCH_3COO(aq) + MnS(s)$

net ionic equation:

$Mn^{+2}(aq) + S^{-2}(aq) \rightarrow MnS(s)$

4. The identity of an unknown solid is to be determined. The compound is one of the seven salts listed in the following table.

~~$Al(NO_3)_3 \cdot 9H_2O$~~	$BaCl_2 \cdot 2H_2O$	~~$CaCO_3$~~	$CuSO_4 \cdot 5H_2O$	~~NaCl~~	~~$BaSO_4$~~	$Ni(NO_3)_2 \cdot 6H_2O$

Use the results of the following observations or laboratory tests to explain how each compound in the table may be eliminated or confirmed. The tests are done in sequence from (a) through (e)

(a) The unknown compound is white. Which two compounds can be eliminated using this observation? (trans. metals form colored solutions)

$CuSO_4 \cdot 5H_2O$, $Ni(NO_3)_2 \cdot 6H_2O$

(b) When the unknown compound is added to water, it dissolves readily. Which two compounds can be further eliminated using this test?

$CaCO_3$, $BaSO_4$ (insoluble in water)

(c) When $AgNO_3$ (aq) is added to an aqueous solution of the unknown compound, a white precipitate forms. Which compound can be further eliminated using this test?

$Al(NO_3)_3 \cdot 9H_2O$ (no precipitate will form when added to $AgNO_3$)

(d) When the unknown compound is carefully heated, it loses mass. Which compound can be further eliminated using this test?

NaCl (not a hydrate, won't lose mass when heated)

(e) Describe a test that can be used to confirm the identity of the unknown compound identified in part (d). Limit your confirmation test to a reaction between an aqueous solution of the unknown compound and an aqueous solution of one of the other soluble salts listed in the table. Describe the expected results of the test; include the formula(s) of any product(s).

unknown = $BaCl_2 \cdot 2H_2O$

ex: mix an aqueous solution of $BaCl_2$ with an aqueous solution of $CuSO_4$. $BaSO_4$ will precipitate.

5. A student is instructed to determine the concentration of a solution of $CoCl_2$ based on absorption of light (spectrometric/colorimetric method). The student is provided with a 0.10 M solution of $CoCl_2$ with which to prepare standard solutions with concentrations of 0.020 M, 0.040 M, 0.060 M, and 0.080 M.

(a) Describe the procedure for diluting the 0.10 M solution to a concentration of 0.020 M using distilled water, a 100 mL volumetric flask, and a pipet or buret. Include specific amounts where appropriate.

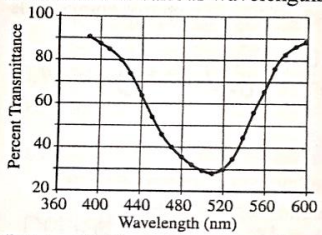
$M_1V_1 = M_2V_2$

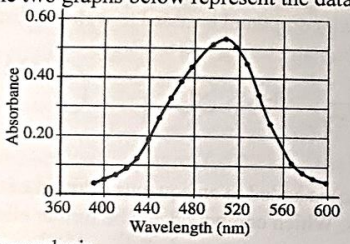
$(0.1)V_1 = (0.02)(100)$

$V_1 = 20\,mL$

pipet 20 mL of 0.10 M $CoCl_2$ into a volumetric flask. Add enough water to reach the 100 mL mark on the flask. Stopper and mix.

The student takes the 0.10 M solution and determines the percent transmittance and the absorbance at various wavelengths. The two graphs below represent the data.

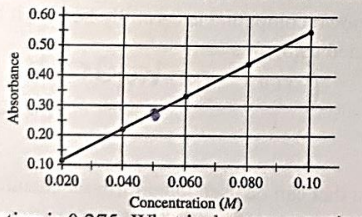




(b) Identify the optimum wavelength for analysis

~510 nm

The student measures the absorbance of the 0.020 M, 0.040 M, 0.060 M, 0.080 M, and 0.10 M solutions. The data are plotted below.



(c) The absorbance of the unknown solution is 0.275. What is the concentration of the solution?

~0.050 M

(d) Beer's Law is an expression that includes three factors that determine the amount of light that passes through a solution. Identify two of these factors.

concentration, pathlength

(e) The student handles the sample container (e.g. test tube or cuvette) that holds the unknown solution and leaves fingerprints in the path of the light beam. How will this affect the calculated concentration of the unknown? Explain your answer.

The fingerprints will also absorb light, resulting in a higher measured absorbance and therefore a higher calculated concentration