CHM 2045
THIRD PROBLEM SET

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QUESTIONS ABOUT GASES

1. Convert the following to the indicated units.
   a. 543 torr to atm b. 1.75 atm to mm Hg (torr) c. 43.2 L to mL
   d. 1.004 g/mL to g/L e. 20 °C to K f. 100 K to °C
2. To convert a pressure reading in mm Hg taken at sea level at the north pole in January to torr, would you add or subtract? Explain.
3. A sample of H_2 gas occupies a volume of 1.18 L at 760 torr.
   a. What volume will the gas occupy at 800 torr?
   b. What volume will it occupy at 0.526 atm?
   c. What is the pressure if the volume is doubled?
4. A sample of He gas occupies a volume of 100 mL at –23 °C.
   a. What is the volume if the temperature is increased to 60 °C?
   b. At what temperature in Celsius will the sample volume be 154 mL?
   c. What is the volume if the temperature is doubled?
5. A 0.250 mol sample of Ar occupies a volume of 400 mL.
   a. What volume will 1.25 mol occupy?
   b. How many moles are there in 320 mL?
   c. What is the volume if the number of moles is doubled?
6. What is the pressure exerted by a sample of gas if the original temperature is quadrupled, the number of moles of sample is cut in half, and the volume is tripled?
7. What is the volume occupied by 35.2 g of N_2 (g) at 35 °C and 741 torr?
8. A 25.0 L cylinder contains 36.6 g He at 10 °C. How many grams of He must be released slowly to reduce the pressure to 1.75 atm while maintaining the temperature at 10°C?
9. If 100 mL of Y weighs 0.316 g at STP, calculate the molecular weight of Y.
10. Ozone (O_3) is an allotrope (different form of an element) of oxygen.
    a. Calculate the density of ozone gas at STP.
    b. Calculate the density of ozone at 25 °C and 700 torr.
11. Gas, Z, is found to be 9.93% C, 58.64% Cl and 31.43% F by mass. If 100 mL of Z has a mass of 0.540 g at STP, determine the empirical formula, the molar mass and the molecular formula for Z.
12. Hydrogen gas and nitrogen gas react under suitable conditions to form NH_3 (g).
    a. Write a balanced equation for this transformation.

b. How many liters of N_2 are needed to combine with 3.0 L of hydrogen at STP?

c. How many liters of NH_3 can be produced? How many moles of NH_3?

d. If 10.0 g of H_2 and 4.0 g N_2 are reacted at STP, how many liters of NH_3 can be formed?

13. Consider a mixture of 96.0 g O_2 and 140 g N_2 at a pressure of 800 torr in a rigid container.

a. What is X_{O_2}?

b. Calculate the partial pressure of N_2?

c. If 12.0 g He are added to this bulb, what is the partial pressure of N_2? What is X_{N_2}?

14. When HCl (g) reacts with NH_3 (g) at laboratory conditions, a white crystalline solid (NH_4Cl) is formed. The equation for this reaction is:

NH_3 (g) + HCl (g) ssd NH_4Cl (s)

Now imagine that some HCl (g) is introduced into the end of a thin glass tube (1.00 m long) and at the same time some NH_3 (g) is introduced into the opposite end of the tube.

a. Will the solid form in the middle of the tube? If not, toward which end will it form? Explain.

b. Use Graham's law to calculate that point in cm where the white ring would form. (i.e., The distance in cm from a given end)

15. Explain the following (recall the postulates of the kinetic molecular theory).

a. A liquid can be made to flow up and through a straw by reducing the air pressure inside the straw.

b. If a quantity of gas is compressed without changing the temperature to half its original volume, it will exert twice the original pressure against the container walls.

c. Heated gas molecules tend to rise.

d. CO_2 gas at STP can be solidified by cooling.

e. The air pressure in an automobile tire rises upon driving at high speeds.

f. A bubble of air formed at the bottom of a pool of water becomes larger as it rises to the surface.

QUESTIONS ABOUT LIQUIDS

16. What would you say is the most drastic difference between a quantity of material in the liquid (or solid) state compared to the same amount of material in the gaseous state?

17. As compared to the gas and solid states, the liquid state is difficult to characterize and define. Why?

18. Ether is a volatile liquid compared to water. What does this mean in terms of intermolecular forces of attraction within each liquid?

19. Does the **strength** of the intermolecular forces in a liquid change as the liquid is heated? Explain. Why does the viscosity decrease with rising temperature?

20. Explain what effect changes in the strength of the intermolecular forces of attraction has on the following properties and why.

    a. Normal boiling point
    b. Density of the liquid
    c. Viscosity of the liquid
    d. Deviation from ideal behavior of the vapor
    e. ΔH_{vap}
    f. Vapor pressure

21. By graphing the K.E. vs. the fraction of molecules show what the distribution of K.E.'s looks like at two temperatures, T_1 and T_2 where $T_2 > T_1$.

    Explain in terms of this graph why the vapor pressure at T_2 is greater than at T_1 .

22. The vapor pressure of isopropyl alcohol is 100 torr at 39.5 °C. If the molar heat of vaporization is 43.7 kJ/mole, what is the normal boiling point of isopropyl alcohol?

QUESTIONS ABOUT IMF's

23. What three types of intermolecular forces of attraction that can exist between identical molecules?

24. How is it possible for a non-polar molecule to induce a dipole in a neighboring non-polar molecule?

25. Does all matter exhibit London attractions? Explain.

26. Which member of the following pairs is expected to have the greater polarizibility? Explain why.

    a) Ar or Xe
    b) $CH_3CH_2CH_2CH_3$ or
    CH_2—CH_2
    |　　|
    CH_2—CH_2
    c) H_2O or H_2Se

27. CO and N_2 have the same approximate molecular weight, 28 amu, yet the normal boiling point of CO is −191 °C while that of N_2 is −196 °C. Explain. (HINT: Think IMF)

28. What types of intermolecular forces exist in samples of the following and what is the **STRONGEST** type of intermolecular force that occurs in that sample?

    a) SO_2
    b) CH_3CH_3
    c) $(CH_3)_2NH$
    d) HCl

29. Which member of the following pairs would you predict to have the higher boiling point? Explain.

    a) CF_4 or CCl_4
    b) LiCl or HCl
    c) NH_3 or PH_3
    d) CH_3CH_3 or CH_3F
    e) $CH_3–C{\equiv}C–CH_3$ or
    CH_2—CH_2
    |　　|
    CH_2—CH_2
    f) $CH_3(CH_2)_{10}CH_3$ or H_2O

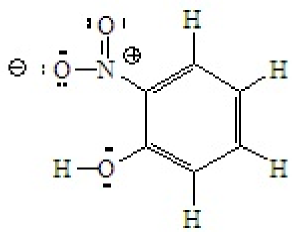
30. Rationalize the trend in boiling points exhibited by the hydrogen halides; HF, HCl, HBr, HI.

31. a) For pairs of molecules in the gas phase, the average H-bond dissociation energy are 17 kJ/mol for NH_3, 22 kJ/mol for H_2O , and 29 kJ/mol for HF. Explain this trend.

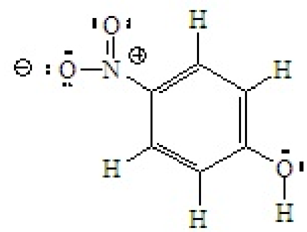
b) The boiling points for NH_3, H_2O, and HF are: −33.34 °C for NH_3 , 100 °C for water, and 19.5 °C for HF. Considering the data given in part a) explain this trend.

32. Consider the molecules drawn below; compound II has a higher boiling point than compound I. Can you rationalize this fact? (HINT: It involves H-bonding)

Compound I



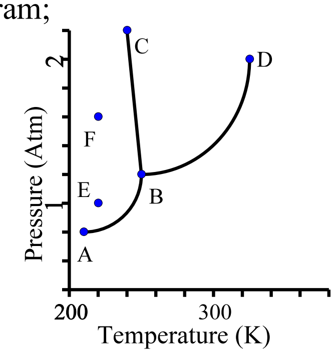
Compound II



QUESTIONS ABOUT SOLIDS

33. Recall (or look it up in your text!) the heating curve for H_2O, ice - liquid - vapor. If you compare the sloping portions of this plot, you'll notice that it requires **more** heat to raise the temperature of liquid H_2O by 1 °C than for either ice or vapor. What does this tell you about the relative specific heats of liquid H_2O vs the other two phases of H_2O?

34. Consider the following phase diagram;



a. What do the line segments, A-B, B-C, and B-D represent respectively?

b. What is the physical state of this substance at STP?

c. If you have a sample of this substance under the conditions represented by point E and heated it at constant pressure, what will happen?

d. If you have a sample of this substance under the conditions represented by point F and heated it at constant pressure, what will happen?

e. What is the significance of point B?

f. Why does the graph stop at point D? Explain.

35. Examine the properties of macromolecules. Do you think that the bonding within macromolecules is more like that in ionic materials or molecular materials? Why?

36. Which substance in each of these pairs would you predict to have the higher melting point?

a) BrCl vs Cl_2	b) CsBr vs BrCl	c) ClF vs BrF
d) Mg vs Br_2	e) C(diamond) vs $C1_2$	f) SF_4 vs SF_6
g) $SiCl_4$ vs $SiBr_4$	h) SiC vs $SiBr_4$	i) H_2O vs H_2S

(Check your predictions by looking up the melting points of these materials in any source book of chemical information, e.g., CRC Handbook of Chemistry of Physics.)

37. In which physical state (solid, liquid, or gas) is it easiest to carry out chemical reactions? Explain.

38. What is the definition of the word "solution?"

39. What are the components of a solution? How are they distinguished?

40. Why are most chemical reactions carried out in liquid solution?

IPF'S IN SOLUTIONS

41. In any two-component solution, what three interactions are present?

42. There are four types of chemical substances: ionic solids (salts), molecular substances, network covalent solids (macromolecules), and metals. Of these, network covalent substances do not usually form solutions and provided no reaction occurs, metals generally form solutions only with other metals (alloys). **Therefore, practical solutions are formed from combinations of the remaining two types of substances, (ionic and molecular substances).** When two substances (one a solute and the other the solvent) are mixed using these remaining two types of substances, there are 10 possible solute-solvent combinations (because molecules come in three forms; polar and nonpolar and H-Bonding molecules).

1) NP − NP	2) P − P
3) H-Bonding - H-Bonding	4) Ionic − Ionic
5) H-Bonding - P	6) NP − P
7) NP - H-Bonding	8) P − Ionic
9) H-Bonding - Ionic	10) NP − Ionic

For each of the above solute-solvent combinations, list the three types of interparticle forces of attraction present in the mixture.

43. Which of all of the possible types of interparticle forces of attraction in a solution is expected to be the strongest based on a two-particle, A-B, interaction?

44. If a liquid solution involving an ionic solute is desired at room temperature, which type of substance would be the best choice for the solvent? Why?

45. When two substances (A and B) are mixed, a homogeneous mixture (a solution) may or may not be formed depending on the relative strengths of the three interparticle forces present in the mixture. Describe the four possible mixing scenarios and explain when a solution is expected.

46. Are each of the following solute-solvent combinations expected to form a solution? Explain.

a) CCl_4 – Hexane
b) Hexane – Water
c) NaCl – Water
d) NaCl – Hexane

47. From question 44 above, it should be clear that water is expected to be a good solvent for ionic solutes. However, from question 43 above, it should be clear that ion-ion forces are stronger than ion-dipole forces. How then is it possible for an ionic compound to dissolve in water with $\Delta H<0$?

48. Hexane and methanol are miscible as gases but only slightly soluble in each other as liquids. Explain.

49. Which saturated solution is more concentrated,

a) KNO_3 in water or b) KNO_3 in CCl_4? Explain.

50. Which saturated solution is more concentrated,

a) $CHCl_3$ in water or b) $CHCl_3$ in hexane? Explain.

51. What is the strongest type of interparticle force between solute and solvent in each of the following mixtures?

a) CsCl in H_2O (ℓ)
b) acetone, $CH_3\overset{\overset{O}{\|}}{C}CH_3$ (ℓ) in H_2O (ℓ)
c) CH_4 (g) in CH_3OH (ℓ)
d) Br_2 (ℓ) in CCl_4 (ℓ)
e) CH_3CH_3 (g) in $CH_3CH_2CH_2NH_2$ (ℓ)
f) CH_3OH (ℓ) in H_2O (ℓ)
g) H_2CO (g) in CH_3OH (ℓ)
h) MgO (s) in hexane (ℓ)

52. Which member of the following pairs is more soluble in liquid diethyl ether ($CH_3CH_2OCH_2CH_3$)? Why?

a) NaCl (s) or HCl (g)
b) He (g) or $CH_3CH_2CH_2Br$ (ℓ)

53. What is the charge density of an ion and what two properties of an ion affect it? How do these properties affect the heat of hydration, ΔH_{hyd}, for an ion?

54. Which ion has the greater charge density? Which ion has the higher ΔH_{hyd}?

a) Na^+ or Cs^+
b) NO_3^- or CO_3^{-2}
c) Br^- or Na^+
d) Fe^{+2} or Fe^{+3}

55. Like NH_4NO_3, a flask containing NH_4Cl in water feels cold to the touch as the salt dissolves.

a) Is the dissolving of NH_4Cl in water exothermic or endothermic?

b) Is the magnitude of ΔH_{lat} of NH_4Cl larger or smaller than the combined ΔH_{hyd} of the two ions? Explain.

c) Given the answer in part (a), why does NH_4Cl dissolve in water?

56. Caffeine is about 10 times as soluble in hot water as in cold water.

a) Is ΔH_{soln} of caffeine in water positive or negative?

b) A chemist puts a hot-water extract of caffeine into an ice bath, and some caffeine crystallizes. Is the remaining liquid saturated, unsaturated, or supersaturated?

57. Use the following data to calculate the combined heats of hydration for the ions in sodium acetate, ($NaC_2H_3O_2$): $\Delta H_{lat} = -763$ kJ/mol $\Delta H_{soln} = 17.3$ kJ/mol

Which ion do you think contributes more to the combined heats of hydration in part (a)? Why?

58. You are given a bottle of solid X and three aqueous solutions of X, one saturated, one unsaturated, and one supersaturated. How would you determine which aqueous solution is which?

59. Why does the solubility of any gas decrease with rising temperature?

60. Consider the following data (in units of g solute / 100 g H_2O):

SOLUTE	**10 °C**	**20 °C**
$AgNO_3$	170.	222.
Li_2CO_3	1.43	1.33
O_2	0.0054	0.0044

a) What is the sign of ΔH_{soln} for each solute?

b) Write an equation the dissolution of each solute with "+ heat" as a reactant or a product.

61. The Henry's law constant (k_H) for O_2 in water at 20 °C is 1.28×10^{-3} mol/L•atm.

a) How many grams of O_2 will dissolve in 2.00 L H_2O at 1.00 atm?

b) How many grams of O_2 will dissolve in 2.00 L H_2O that is in contact with air, in which the partial pressure of O_2 is 0.209 atm?

62. Individuals with respiratory problems are often treated with devices that deliver air with a higher partial pressure of O_2 than in normal air. Why?

QUESTIONS ABOUT SOLUTION CONCENTRATION

63. Discuss an experimental method to determine whether or not a compound is molecular or ionic.

64. Consider the formulas: HOH, NaOH, HCl, NaCl. Which are predicted to be molecular materials? Which are expected to be ionic materials? Explain.

65. What is unusual about the composition of salts such as NH_4Cl or $(NH_4)_2SO_4$?

66. For solutions, what are electrolytes? What are nonelectrolytes?

67. What is necessary for a substance to conduct electricity? Explain.

68. Why does solid NaCl not conduct electricity but an aqueous solution of NaCl does?

69. Give all possible ways one can get ions into solution. Explain!

70. If a solute is known to be a nonelectrolyte in solution, what, if anything, can one infer about the type of bonding in the pure solute?

71. If a solute is known to be an electrolyte in solution, what, if anything, can one infer about the type of bonding in the pure solute?

72. A solution of isopropanol (C_3H_7OH) is made by dissolving 0.30 mol isopropanol in 0.80 mol water.
    a) What is the mole fraction of isopropanol?
    b) What is the mass percent of isopropanol?
    c) What is the molality of isopropanol?

73. What mass of CsCl must be added to 0.500 L of water to produce a 6.30 % CsCl solution? (Assume the density of water is 0.9970 g/mL.)

74. Calculate the molality and mass % of glycine (NH_2CH_2COOH) in a solution containing 88.4 g glycine dissolved in 1.250 kg H_2O.

75. An 8.00 % aqueous solution of ammonia has a density of 0.9651 g/mL. Calculate the molality, molarity, and the mole fraction of NH_3.

76. Generally, what is the most "convenient" concentration unit for chemists to use? Why?

77. What is the definition of "Molarity?"

78. What is the molarity of sugar, $C_{12}H_{22}O_{11}$, if 53.5 g of sugar are dissolved to give 746 mL of solution?

79. What is the molarity of KCl if 1.45 g of KCl are dissolved to give 50.0 mL of solution?

80. How many grams of $NaNO_3$ are there in 75.0 mL of 1.00 M $NaNO_3$ solution?

81. How many grams of NaCl are in 500 g of each of the following solutions?

    a) 1.00 m NaCl

    b) 1.00 M NaCl if the density of the solution is 1.025 g/mL.

    c) 5.00 % NaCl

82. Calculate the molarity of these aqueous solutions:

    a) 42.3 g sucrose ($C_{12}H_{22}O_{11}$) in 100.0 mL of solution.

    b) 5.50 g $LiNO_3$ in 5050 mL of solution.

    c) 75.0 mL of 0.250 M NaOH diluted to 0.250 L with water.

83. How would you prepare these aqueous solutions:

    a) 250 mL of 8.73×10^{-2} M KH_2PO_4 from solid KH_2PO_4?

    b) 500 mL of 0.320 M NaOH from 1.25 M NaOH?