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Archery – Solids, Liquids, and Gases Practice Problems

Gas Laws

1. A 40.0 L tank of ammonia has a pressure of 8.00 atm. Calculate the volume of the ammonia if its pressure is changed to 12.0 atm while its temperature remains constant.

$V_i = 40.0\ L$
$P_i = 8.0\ atm$
$P_f = 12\ atm$
$V_f = ?$

$P_iV_i = P_fV_f$
$\frac{(8)(40)}{12} = \frac{(12)(V_f)}{12}$
$26.7\ L = V_f$

2. 2.00 liters of hydrogen, originally at 25.0 °C and 0.98 atm, are heated until a volume of 20.0 liters and a pressure of 3.50 atmospheres is reached. What is the new temperature?

$V_i = 2\ L$
$T_i = 25 + 273.15 = 298.15\ K$
$P_i = 0.98\ atm$
$T_f = ?$
$V_f = 20\ L \quad P_f = 3.50\ atm$

$\frac{P_iV_i}{T_i} = \frac{P_fV_f}{T_f}$
$\frac{(2)(0.98)}{298.15} = \frac{(20)(3.5)}{T_f}$
$\frac{1.96T_f}{1.96} = \frac{20870.5}{1.96}$
$T_f = 11,000\ K$

3. A gas is collected and it has a volume of 720.0 mL of a gas collected at 20.0 °C and 3.00 atm pressure. What is the volume at if the gas is changed to STP?

$V_i = 720.0\ mL$
$T_i = 293.15\ K$
$P_i = 3.00\ atm$
$P_f = 1\ atm$
$T_f = 273.15$

$\frac{P_iV_i}{T_i} = \frac{P_fV_f}{T_f}$
$\frac{(3)(0.72)}{293.15} = \frac{(1)V_f}{273.15}$
$\frac{590.004}{293.15} = \frac{293.15V_f}{293.15}$
$2.01\ L = V_f$

Ideal Gas Law

4. What is the density of carbon dioxide at 350 K and 1.0 atm?

$d = \frac{P \cdot MW}{RT} = \frac{(1)(44.01\ g/mol)}{(0.0821)(350)}$
$1.5\ g/L$

$CO_2 = 12.01 + 16 + 16 = 44.01\ g/mol$

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5.Find the number of grams of O_2 that exert a pressure of 600 torr at a volume of 32.5 L and a temperature of 26 °C.

$P = 600 \text{ torr}\left(\frac{1}{760}\right) = 0.789 \text{ atm}$

$V = 32.5 \text{ L}$

$T = 26 + 273.15 = 299.15 \text{ K}$

$PV = nRT$

$n = \frac{PV}{RT} = \frac{(0.789)(32.5)}{(0.0821)(299.15)} = 1.04 \text{ mol}$

$1.04 \text{ mol}\left(\frac{32 \text{ g}}{\text{mol}}\right) = \boxed{33 \text{ g}}$

6. An elemental gas has a mass of 10.3 g. If the volume is 58.4 L and the pressure is 758 torr at a temperature of 2.5 °C, what is the gas?

$m = 10.3 \text{ g}$

$V = 58.4 \text{ L}$

$P = 758\left(\frac{1}{760}\right) = 0.997$

$T = 2.5 + 273.15 = 275.65 \text{ K}$

$n = \frac{(0.997)(58.4)}{(0.0821)(275.65)} = 2.57 \text{ mol}$

$MW = \frac{g}{mol} = \frac{10.3}{2.57} = \boxed{4 \text{ g/mol}}$

$\boxed{He}$

7. 10 L of an unknown gas has a mass of 10.8 grams at a temperature of 310 K and 1.2 atm. What is the molar mass of this mass? What is the identity of the gas?

$V = 10 \text{ L}$

$m = 10.3 \text{ g}$

$T = 310 \text{ K}$

$P = 1.2 \text{ atm}$

$n = \frac{PV}{RT} = \frac{(1.2)(10)}{(0.0821)(310)} = 0.47 \text{ mol}$

$MW = \frac{m}{n} = \frac{10.3}{0.47} = \boxed{21.9 \text{ g/mol}}$

8. A sample containing 1.5 mole of potassium chlorate is heated until it decomposes to potassium chloride and oxygen gas. The oxygen is collected in an inverted bottle through the displacement of water. Answer the following questions using this information.

a. Write a balanced chemical equation for this reaction

$$2\,KClO_3 \longrightarrow 2\,KCl + 3\,O_2$$

b. How many moles of oxygen are produced?

$n_{KClO_3} = 1.5 \text{ mol}$

$1.5 \text{ mol } KClO_3\left(\frac{3\,O_2}{2\,KClO_3}\right) = \boxed{2.25 \text{ mol } O_2}$

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c. The temperature and pressure of the sample are adjusted to STP. The volume of the sample is found to be slightly greater than 22.4 L. Explain this observation.

You have more than 1 mole of sample. 1 mol of gas can occupy 22.4 L. If you have more than 1 mole (like we do), then the volume should be higher

d. An excess of sulfur is burned in the oxygen. Write a balanced chemical equation and calculate the number of moles of gas formed.

$S_8 + 8O_2 \longrightarrow 8SO_2$

$2.25 \text{ moles } O_2 \left(\frac{8}{8}\right) = \boxed{2.25 \text{ moles } SO_2}$

9.

$$2\ KClO_3\ (s) \rightarrow 2\ KCl\ (s) + 3\ O_2\ (g)$$

The reaction above took place, and 1.75 liters of oxygen gas were collected over water at a temperature of 29 °C and pressure of 765 mm Hg. The vapor pressure of water at 29 °C is 30.0 mm Hg.

a. What is the partial pressure of the oxygen gas collected?

$P_{O_2} = 765 - 30 = \boxed{735 \text{ mm Hg}}$

b. How many moles of oxygen gas were collected?

$P = 735 \text{ mm Hg}\left(\frac{1}{760}\right) = 0.967 \text{ atm}$

$n = \frac{PV}{RT} = \frac{(0.967)(1.75)}{(0.0821)(302.15)}$

$\boxed{n = 0.068 \text{ mol}}$

c. What would be the dry volume of the oxygen gas at a pressure of 760 mm Hg and a temperature of 273 K?

$V = \frac{nRT}{P} = \frac{(0.068)(0.821)(273)}{1 \text{ atm}} = \boxed{15.2 \text{ L}}$

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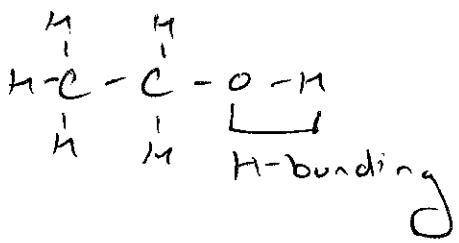
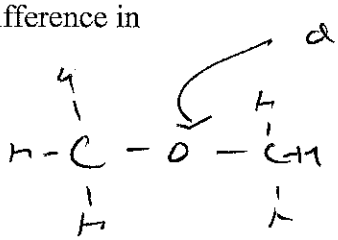
Intermolecular Forces

10. CH_3CH_2OH boils at 78 °C and CH_3OCH_3 boils at - 24 °C, although both compounds have the same composition. This difference in boiling points may be attributed to a difference in

(A) molecular mass
(B) density
(C) specific heat
(D) hydrogen bonding
(E) heat of combustion





11.

Hydrogen Halide	Normal Boiling Point, °C
HF	+19
HCl	- 85
HBr	- 67
HI	- 35

The liquefied hydrogen halides have the normal boiling points given above. The relatively high boiling point of HF can be correctly explained by which of the followng?

(A) HF gas is more ideal.
(B) HF is the strongest acid.
(C) HF molecules have a smaller dipole moment.
(D) HF is much less soluble in water.
(E) HF molecules tend to form hydrogen bonds.

12. Choose the molecule that has the strongest dispersion force. Justify your response:

a. H_2O and H_2S

↑ The heavier the molecule, the more dispersion forces it has

b. CO_2 and CO

↑ Heavier molecule : ↑ number of dispersion forces

13. Rationalize the difference in boiling points in each pair:

a. HF (20 °C) and HCl (-85 °C)

HF has hydrogen bonding whereas HCl does not (it only has dipole-dipole)

b. $CHCl_3$ (61 °C) and $CHBr_3$ (150 °C)

Br has a stronger dispersion force due to its heavier weight.

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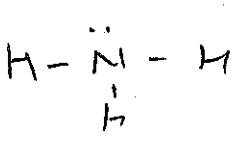
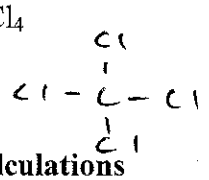
14. Identify the intermolecular force(s) in the following molecules:

a. NH_3



- Dispersion
- Dipole-Dipole
- Hydrogen Bonding

d. CCl_4



- Dispersion

Solution Calculations

15. Ascorbic acid (vitamin C, $C_6H_8O_6$) is a water – soluble vitamin. A solution containing 80.5 g of ascorbic acid dissolved in 210 g of water has a density of 1.22 g/mL at 55 °C.

a. Calculate the mass percent of ascorbic acid

$$\%\ \text{mass} = \frac{80.5}{210} \times 100\% = \boxed{38\%}$$

b. Calculate the mole fraction of ascorbic acid

$$X = \frac{\text{mol acid}}{\text{total moles}} = \frac{0.4}{(11.6 + 0.4)} = \boxed{0.033}$$

$$210\ \text{g}\ H_2O\left(\frac{1\ \text{mol}}{18.02\ \text{g}}\right) = 11.6\ \text{mol}\ H_2O \qquad 80.5\ \text{g}\left(\frac{1}{176.064}\right) = 0.4\ \text{mol}$$

c. The molality

d. The molarity of ascorbic acid

$$210\ \text{g}\left(\frac{\text{mL}}{1.22\ \text{g}}\right) = 172.1\ \text{mL} = 0.1721\ \text{L}$$

$$[\text{Vit C}] = \frac{0.4}{0.1721} = \boxed{2.3\ \text{M}}$$

$$m = \frac{\text{mol}}{\text{kg}} = \frac{0.4\ \text{mol}}{0.210\ \text{kg}} = \boxed{1.9\ m}$$

16. Calculate the number of moles of solute present in each of the following aqueous solutions:

a. 600 mL of 0.250 M $SrBr_2$

$$0.6\ \text{L}\left(\frac{0.250\ \text{mol}}{\text{L}}\right) = \boxed{0.15\ \text{mol}}$$

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b. 86.4 g of 0.180 m KCl

$0.0864\ kg \times \frac{0.180\ mol}{1\ kg} = 0.0156\ mol$

Raoult's Law

17. Glycerin ($C_3H_8O_3$) is a nonvolatile electrolyte with a density of 1.26 g/mL at 25 °C. Calculate the vapor pressure of 25 °C of a solution made by adding 50.0 mL of glycerin to 500.0 mL of water. The vapor pressure of pure water at 25 °C is 23.8 torr and its density is 1.00 g/mL

$d = 1.26\ g/mL$

$P_{sol} = ?$

$V_{gly} = 50.0\ mL$

$V_{H_2O} = 500.0\ mL$

$P_{H_2O} = 23.8\ torr$

$P_{solution} = X_{solvent} P^{\circ}_{solvent}$

$0.05\ mL \times \frac{1.26\ g}{mL} \times \frac{1\ mol}{92.094} = 6.8 \times 10^{-4}\ mol$

$0.5\ mL \times \frac{1.00\ g}{mL} \times \frac{1}{18.002} = 2.77 \times 10^{-2}\ mol$

$X_{solvent} = \frac{2.77 \times 10^{-2}}{(6.8 \times 10^{-4}) + (2.77 \times 10^{-2})} = 0.978$

$P = (0.978)(23.8)$

$P = 23.3\ torr$

18. Calculate the vapor pressure of water above a solution prepared by adding 22.5 g of lactose ($C_{12}H_{22}O_{11}$) to 200.0 g of water at 338 K. The vapor pressure. P_{H2O} at this temperature is 187.5 torr

$22.5\ g \left(\frac{1}{342.296}\right) = 6.6 \times 10^{-2}$

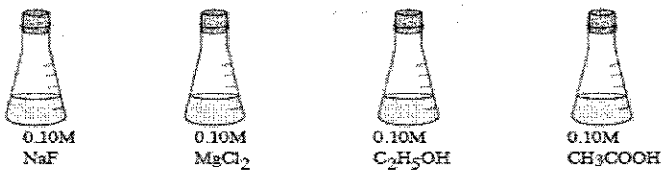
$200.0\ g \left(\frac{1}{18.02}\right) = 11.1\ mol$

$X = \frac{11.1}{11.1 + 0.0657} = 0.994$

$P = (187.5)(0.994) = 186.4\ torr$

Colligative Properties

19.



Answer the following questions, which refer to the 100 mL samples of aqueous solutions at 25°C in the stoppered flasks shown above.

(a) Which solution has the lowest electrical conductivity? Explain.

Both C_2H_5OH and CH_3COOH are weak acids, so they will conduct the least.

(b) Which solution has the lowest freezing point? Explain.

C_2H_5OH; has H-bonds and weighs more than CH_3COOH, so it freezes at the lowest temp.

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20. Which of the following aqueous solutions will have the highest boiling point?
   a. 0.1 m Sodium Chloride $NaCl$
   b. 0.1 m Potassium Fluoride KF
   c. 0.1 m Magnesium Chloride $MgCl_2$
   d. 0.1 m Sugar (Sucrose) Solution $C_{12}H_{22}O_{11}$
   e. 0.1 m Potassium Nitrate KNO_3

21. What is the boiling point of a solution that contains 50.0 grams of sucrose ($C_{12}H_{22}O_{11}$) dissolved in 2000. grams of water? The K_b for water is 0.51 °C kg/mol.

$\Delta T_b = i K_b m$

$50\text{ g}\left(\frac{1\text{ mol}}{342.296\text{ g}}\right) = 0.146\text{ mol}$

$m = \frac{0.146}{2\text{ kg}} = 0.073\text{ m}$

$\Delta T_b = (1)(0.51)(0.073)$

$\Delta T_b = 0.037\text{ °C}$ (new $T_b = 100.037$ °C)

22. What is the freezing point of a solution that contains 15.0 grams of phenol (C_6H_5OH) dissolved in 275 grams of water? The K_f for water is 1.86 °C kg/mol

$15.0\text{ g}\left(\frac{1}{94.108}\right) = 0.159\text{ mol}$

$m = \frac{0.159\text{ mol}}{0.275\text{ kg}} = 0.579$

$\Delta T_f = (1)(1.86)(0.579)$

$\Delta T_f = 1.08\text{ °C}$

$T_f = 0 - 1.08 = \boxed{-1.08\text{ °C}}$

23. A 0.7549 g sample of $C_xH_yO_z$ burns to make 1.9061 g CO_2 and 0.3370 g H_2O. Also, in a different experiment, a 0.5246 gram sample was dissolved in 10 g of lauric acid and the freezing point was lowered by 1.68 °C.
   a. What is the empirical formula of the substance?

$C_xH_yO_z + O_2 \longrightarrow CO_2 + H_2O$

All carbon goes here. All H goes here.

$1.9061\text{ g } CO_2\left(\frac{1\text{ mol}}{44.01\text{ g}}\right)\left(\frac{1\text{ C}}{1\text{ CO}_2}\right) = 0.0433\text{ mol C}\left(\frac{12.01\text{ g}}{1}\right) = 0.5202\text{ g C}$

$0.3370\text{ g } H_2O\left(\frac{1}{18.02}\right)\left(\frac{2\text{ H}}{1\text{ H}_2O}\right) = 0.0374\text{ mol H}\left(\frac{1.008}{1}\right) = 0.0377\text{ g H}$

$m_{Oxygen} = 0.7549 - 0.5202 - 0.0377 = 0.197\text{ g}\left(\frac{1}{16}\right) = 0.0123\text{ mol}$

$\frac{0.123}{0.0123} = 1 \quad \frac{0.0433}{0.0123} = 3.5 \quad \frac{0.0374}{0.0123} = 3$

$\boxed{C_7H_6O_2}$

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b. If K_f of lauric acid is 3.90 °C/m, calculate the molar mass of the substance.

$$\Delta T_f = i K_f m$$

$$m = \frac{\Delta T_f}{i K_f} = \frac{1.68}{(1)(3.9)} = 0.43\ m$$

$$0.43 = \frac{mol}{0.01\ kg\ lauric\ acid}$$

$$0.0043\ mol = mol\ unknown$$

$$MW = \frac{0.7549}{0.0043}$$

$$MW = 175.6\ g/mol$$

c. What is the molecular formula of the substance?

$$C_7H_6O_2 = 122.11\ g$$

$$2[C_7H_6O_2] = C_{14}H_{12}O_4$$