"Fun with Gases" Study Sheet!
(also featuring "fun with solutions.")

Name: Sarah Seat #_____

1. A flask contains 10.0 grams oxygen gas, 20.0 grams nitrogen gas, and 10.0 grams of helium gas. Total pressure in the flask is 2.00 atmospheres.

a. What is the partial pressure of each gas in the flask?

$(10.0\text{ g } O_2)\left(\frac{1\text{ mole}}{31.9988\text{ g}}\right) = 0.31251\text{ moles}$

$(20.0\text{ g } N_2)\left(\frac{1\text{ mole}}{28.0134\text{ g}}\right) = 0.71394\text{ moles}$

$(10.0\text{ g He})\left(\frac{1\text{ mole}}{4.0026\text{ g}}\right) = 2.4984\text{ moles}$

$.31251 + .71394 + 2.4984 = 3.5248$ moles

$X_{O_2} = \frac{0.31251}{3.5248} = 0.08866$

$X_{N_2} = \frac{0.71394}{3.5248} = 0.20255$

$X_{He} = \frac{2.4984}{3.5248} = 0.70880$

$P_{O_2} = P_{TOTAL} \cdot X_{O_2} = (2.00\text{ atm})(.08866) = 0.17732$

$P_{N_2} = P_{TOTAL} \cdot X_{N_2} = (2.00\text{ atm})(.20255) = 0.4051$

$P_{He} = P_{TOTAL} \cdot X_{He} = (2.00\text{ atm})(.70880) = 1.4176$

$P_{O_2} = 0.177\text{ atm}$

$P_{N_2} = 0.405\text{ atm}$

$P_{He} = 1.42\text{ atm}$

b. If the volume of the flask is 40.0 liters, what is the temperature in °C?

$PV = nRT \qquad T = \frac{PV}{nR} = \frac{(2.00\text{ atm})(40.0\text{ L})}{(3.5248\text{ moles})(.0821\frac{\text{L-atm}}{\text{mol.K}})} = 276.45\text{ K}$

3 °C

c. How does the rms speed of the helium compare to that of oxygen?

$\frac{V_{He}}{V_{O_2}} = \left(\frac{M_{O_2}}{M_{He}}\right)^{1/2} = \left(\frac{31.9988}{4.0026}\right)^{1/2} = 2.8275$

(so He's rms speed is 2.8275 times greater than O_2's rms speed)

d. How does the kinetic energy of oxygen compare to that of nitrogen?

They are the same since at same temperature.

2. A gas sample occupies 30.0 liters and contains 85.7 grams of gas at STP. so at 0°C, 1 atm

a. What is the molar mass of the gas?

$(30.0\text{ L})\left(\frac{1\text{ mole}}{22.4\text{ L}}\right) = 1.3393\text{ moles}$

(we can use this since @ STP)

$\frac{85.7\text{ g}}{1.3393\text{ moles}} = 63.989$

$64.0\frac{\text{g}}{\text{mole}}$

b. What would be the volume of this gas at 100.°C and 0.500 atm?

$V = nRT/P = \frac{(1.3393\text{ moles})(.0821\frac{\text{L-atm}}{\text{mol.K}})(373\text{ K})}{0.500\text{ atm}} = 82.0\text{ Liters}$

(or could do $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$)

c. What was the r.m.s. speed of these molecules at STP?

$V_{rms} = \left(\frac{3RT}{M}\right)^{1/2} = \left(\frac{3(8.314\text{ J/mol.K})(273\text{ K})}{(63.989\frac{\text{g}}{\text{mole}})(\frac{1\text{ kg}}{1000\text{ g}})}\right)^{1/2} = 326\text{ m/s}$

must use kilograms for mass to cancel w/ the kg in Joules.

3. $Mg + 2\,HCl \text{ ------> } MgCl_2 + H_{2(g)}$

The hydrogen gas from the above reaction is collected by water displacement. 45.2 mL of gas are collected at 22 °C at a total pressure of 755 mmHg.

a. What mass of HCl must have reacted, assuming 100% yield? ← looked up on VP chart

$P_{H_2} = P_{TOTAL} - P_{H_2O} = 755\ mm\,Hg - 19.83\ mm\,Hg = 735.17\ mm\,Hg$

$n_{H_2} = \frac{P_{H_2}V}{RT} = \frac{\left(\frac{735.17}{760.}\ atm\right)(.0452\,L)}{\left(.0821\ \frac{L\cdot atm}{mol\cdot K}\right)(295\,K)} = .00180529\ moles\ H_2$

$(.00180529\ moles\ H_2)\left(\frac{2\ mole\ HCl}{1\ mole\ H_2}\right)\left(\frac{36.4609\ g}{1\ mole}\right) = \boxed{0.132\ grams\ HCl}$

b. In the gas collected, calculate the mole fraction of hydrogen gas and the mole fraction of water vapor.

$P_{H_2} = P_{TOTAL} \cdot X_{H_2}$

$735.17\ mm\,Hg = (755\ mm\,Hg)(X_{H_2})$

$\boxed{X_{H_2} = 0.974}$

$P_{H_2O} = P_{TOTAL} \cdot X_{H_2O}$

$X_{H_2O} = P_{H_2O} / P_{TOTAL}$

$X_{H_2O} = 19.83\ mm\,Hg / 755\ mm\,Hg$

or could just do $1 - X_{H_2}$ → $\boxed{X_{H_2O} = 0.0263}$

4a. Two balloons are at the same temperature and pressure. One contains Helium and one contains Radon. If an equal sized hole is poked in each balloon, compare the initial deflation rates of these balloons. (The escape of the gases through the tiny hole is called "effusion.")

$\frac{r_{He}}{r_{Rn}} = \sqrt{\frac{M_{Rn}}{M_{He}}} = \sqrt{\frac{222.02\ amu}{4.0026\ amu}} = \boxed{7.4477 = \frac{r_{He}}{r_{Rn}}}$

(He's rate is 7.4477 times faster)

b. Another gas is found to have an effusion rate that is 2.7 times that of radon, when at the same conditions. Calculate the molar mass of the gas.

$\frac{r_x}{r_{Rn}} = \left(\frac{M_{Rn}}{M_x}\right)^{1/2} = 2.7 \qquad \left(\frac{222.02}{M_x}\right)^{1/2} = 2.7 \qquad \frac{222.02}{M_x} = (2.7)^2$

$M_x = 30.455 \rightarrow \boxed{30.\ g/mole}$

5. At 100.°C and 0.800 atm, a gas has a density of 9.20 grams per liter. What is the molar mass of the gas?

Assume we have 1 mole:

$V = \frac{nRT}{P} = \frac{(1\,mole)\left(.0821\ \frac{L\cdot atm}{mol\cdot K}\right)(373\,K)}{0.800\ atm} = 38.279\ L$ occupied by 1 mole

$(9.20\ g/L)\left(\frac{38.279\ L}{1\ mole}\right) = \boxed{352\ g/mole}$

6a. Suppose an alloy called "alumigold" contained only aluminum and gold.
5.00 grams of the alloy are reacted with HCl, and 3.33 liters of hydrogen gas are collected over water at 50.°C and an atmospheric pressure of 770. mmHg. What percent (by mass) of the alumigold is gold?
(Hint: use the activity series to see which metal can actually react with HCl, and write that balanced equation. Then you'll know that all of the hydrogen gas produced came from that metal.)

$Au + HCl \rightarrow NR$

$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3\,(aq)} + 3H_{2(g)}$

all the H_2 gas produced must be from the rxn between HCl and Al

$P_{TOTAL} = P_{H_2} + VP_{H_2O}$

$P_{H_2} = P_{TOTAL} - VP_{H_2O}$

looked up on cndt

$P_{H_2} = 770.\ mmHg - 92.5\ mmHg = 677.5\ mmHg$

$n_{H_2} = \frac{P_{H_2}V}{RT} = \frac{\left(\frac{677.5}{760.}\ atm\right)(3.33\ L)}{\left(.0821\ \frac{L\cdot atm}{mol\cdot K}\right)(323\ K)}$

$n_{H_2} = 0.111942\ moles$

$(.111942\ moles\ H_2)\left(\frac{2\ mole\ Al}{3\ mole\ H_2}\right)\left(\frac{26.9815\ g}{1\ mole}\right) = 2.0136\ g\ Al$

$\frac{2.0136\ g}{5.00\ g} \times 100 = 40.3\%\ Al$

59.7 % Au

7a. Complete and balance: $Mg_{(s)} + 2HBr_{(aq)} \text{------>} MgBr_{2(aq)} + H_{2(g)}$

b. 500. mL of 0.30 Molar HBr react with an excess of magnesium powder.
What volume of gas should be collected, if the gas is collected at 40.°C and 762 mmHg total pressure?
Report your answer in milliliters.

$(0.500\ L)\left(0.30\ \frac{moles}{L}\right) = 0.15\ moles\ HBr$

$(0.15\ moles\ HBr)\left(\frac{1\ mole\ H_2}{2\ mole\ HBr}\right) = 0.075\ moles\ H_2$

$P_{H_2} = P_{TOTAL} - VP_{H_2O} = 762\ mmHg - 55.3\ mmHg = 706.7\ mmHg$

$V = \frac{nRT}{P} = \frac{(.075\ moles)\left(.0821\ \frac{L\cdot atm}{mol\cdot K}\right)(313\ K)}{(706.7/760)\ atm} = 2.0727\ L \rightarrow 2072.7\ mL$

2100 mL

c. In the gas that was collected, what was the mole fraction of the water vapor?

$P_{H_2O} = P_{TOTAL} \cdot X_{H_2O}$

$X_{H_2O} = \frac{P_{H_2O}}{P_{TOTAL}} = \frac{55.3\ mmHg}{762\ mmHg} = 0.0726$

8. $6\,HNO_{3(aq)} + 2\,Al_{(s)} \text{------>} 2\,Al(NO_3)_{3\,(aq)} + 3\,H_{2(g)}$

248 mL of 1.5 M nitric acid are allowed to react with an excess of aluminum powder.
The gas is collected by water displacement at a temperature of 30.°C and an overall pressure of 751 mmHg.
If 4.61 liters of gas are collected, what was the percent yield?

$P_{H_2} = P_{TOTAL} - VP_{H_2O} = 751\ mmHg - 31.82\ mmHg$

$P_{H_2} = 719.18\ mmHg$

$(0.248\ L)\left(\frac{1.5\ mole\ HNO_3}{Liter}\right)\left(\frac{3\ mole\ H_2}{6\ mole\ HNO_3}\right) = 0.186\ moles\ H_2\ expected$

$V_{H_2} = \frac{n_{H_2}RT}{P_{H_2}} = \frac{(.186\ moles)\left(.0821\ \frac{L\cdot atm}{mol\cdot K}\right)(303\ K)}{(719.18\ mmHg)\left(\frac{1\ atm}{760\ mmHg}\right)} = 4.88962\ L\ expected$

$\%\ yield = \frac{actual}{expected} \times 100 = \frac{4.61\ L}{4.88962\ L} \times 100 = 94.3\ \%$

or you could divide mole values

9. Consider the data shown here:

Data for compound #1:
Solubility at 25 °C : 34.9 g compound per 100 mL water
Solubility at 100 °C : 29.2 g compound per 100 mL water
$\Delta H_{solution}$ = +31 kJ/mole or -31 kJ/mole (?)

) more soluble at low temp so ΔH is ⊖

Data for compound #2:
Solubility at 0 °C : 5 g compound per 100 mL water
Solubility at 45 °C : 35 g compound per 100 mL water
$\Delta H_{solution}$ = +67 kJ/mole or -67 kJ/mole (?)

) more soluble at high temp so ΔH is ⊕

a. Determine the $\Delta H_{solution}$ of each compound, including the correct sign.

Compound #1: −31 KJ/mole Compound #2 +67 KJ/mole

b. The two compounds correspond to lithium sulfate, and potassium dichromate.
Write the formula for each compound:
Lithium sulfate Li_2SO_4 (Li^{+1}/SO_4^{-2}) potassium dichromate: $K_2Cr_2O_7$ ($K^{+1}/Cr_2O_7^{-2}$)

c. When lithium sulfate dissolves into water, the water's temperature becomes slightly lower. ← so ΔH is ⊕ (endo)
Which compound is the lithium sulfate (#1 or #2)? #2

d. What is the total concentration (molarity) of ions in a 0.01 Molar lithium sulfate solution? .03 M
What is the total concentration of ions in a 0.01 Molar potassium dichromate solution? .03 M

e. Are these two compounds strong, weak, or non electrolytes? strong electrolytes

(The next 3 problems are from chapter 4, so the answers will be the chapter 4 PDF.)

10a. Classify each compound as a non-electrolyte, a strong electrolyte, or a weak electrolyte:
(Note: the 7 common strong acids are HCl, HBr, HI, HNO_3, $HClO_3$, $HClO_4$, and H_2SO_4. ← strong acids are strong electrolytes
Assume that all other acids are weak unless otherwise told.)
↖ weak acids are weak electrolytes

HCN	weak	SBr_2	non	$MgSO_4$	strong
HClO	weak	$C_4H_6O_2$	non	$C_5H_{10}O_3$	non
KNO_3	strong	HF	weak	Na_2CO_3	strong
BCl_3	non	$FeCl_3$	strong	HNO_3	strong

(Covalent compounds are typically non electrolytes, unless they are acids)

b. Determine the total ion concentration in each solution, below.

0.10 M $Al(NO_3)_3$	0.20 M $(NH_4)_2SO_4$	0.30 M KOH	0.50 M $BaCl_2$
×4 → 0.40 M	×3 → 0.60 M	×2 → 0.60 M	×3 → 1.5 M

c. Determine the total concentration of bromide ion in each solution, below.

0.20 M NH_4Br	0.00010 M $SnBr_4$	0.030 M $FeBr_3$
0.20 M ×1	0.00040 M ×4	0.090 M ×3

11. A solution of lead II nitrate was prepared as follows:
14.82 g of solid $Pb(NO_3)_2$ and 150.0 mL water were added to a container and stirred until the solid fully dissolved. After mixing, the total solution volume came to 152.2 mL.

So, 150.0 g H_2O since H_2O's density is 1 g/mL

a. Calculate the density of the solution.

$$\text{Density of solution} = \frac{\text{Mass solution}}{\text{Volume solution}} = \frac{14.82\text{g} + 150.0\text{g}}{152.2\text{mL}} = \frac{164.82\text{g}}{152.2\text{mL}} = 1.08292$$

1.083 g/mL

b. Calculate the concentration of lead II nitrate in the solution (use molarity units).

$$(14.82\text{g})\left(\frac{1\text{mole}}{331.2098\text{g}}\right) = 0.044745 \text{ moles } Pb(NO_3)_2$$

$$\text{Molarity} = \frac{\text{moles solute}}{\text{L soln}} = \frac{.044745\text{ moles}}{0.1522\text{L}} = 0.293989 \rightarrow 0.2940\text{ M}$$

c. Calculate the total concentration of ions in the solution.

$$(0.293989 \text{ moles } Pb(NO_3)_2)\left(\frac{3\text{ moles ions}}{1\text{mole } Pb(NO_3)_2}\right) = 0.88197 \rightarrow 0.8820\text{M}$$

d. Determine the concentration of Pb^{+2} ion in the solution: $[Pb^{+2}]$ = 0.2940 M
e. Determine the concentration of NO_3^{-1} ion in the solution: $[NO_3^{-1}]$ = 0.5880 M ×2

12. A solution with a total volume of 350. mL was made by adding 39.97 grams of sodium molybdate dihydrate ($Na_2MoO_4 \cdot 2\ H_2O$) to 338 mL of water, and stirring until the solid dissolved. Anhydrous sodium molybdate has a molar mass of 205.93 amu.

so $Na_2MoO_4 \cdot 2H_2O$ molar mass is $205.93 + 2(18.0152) = 241.9604$ g/mole

a. Calculate the concentration of sodium molybdate in mole/L.

$$\frac{\left(39.97\text{ g} \times \frac{1\text{ mole}}{241.9604\text{ g}}\right)}{0.350\text{ L}} = 0.47198 \rightarrow \boxed{0.472\text{ M}}$$

b. Calculate the density of the solution.

$$D = \frac{m}{V} = \frac{39.97\text{g} + 338\text{ g}}{350.\text{ mL}} = 1.07991 \rightarrow \boxed{1.08\text{ g/mL}}$$

c. What mass of anhydrous sodium molybdate would be required to make 250. mL of 0.15 M solution?

$$(0.250\text{ L})\left(\frac{0.15\text{ mole}}{\text{L}}\right)\left(\frac{205.93\text{g}}{\text{mole}}\right) = 7.722 \rightarrow \boxed{7.7\text{ grams } Na_2MoO_4 \cdot 2H_2O}$$

13. Suppose 150. mL of 2.00 Molar $Ba(NO_3)_2$ are mixed with 250. mL of 0.10 M of $Al(NO_3)_3$. Calculate the concentration of nitrate ion in the new solution, after mixing. Assume volumes are additive.

Total (new) volume = 150. mL + 250. mL = 400. mL

$Ba(NO_3)_2$: $M_1V_1 = M_2V_2$

$(2.00\text{ M})(150.\text{mL}) = M_2(400.\text{mL})$

$M_2 = 0.750$ M $Ba(NO_3)_2$

$[NO_3^{-1}] = 2(0.750\text{ M}) = 1.50$ M

$Al(NO_3)_3$: $M_1V_1 = M_2V_2$

$(.10\text{ M})(250.\text{mL}) = M_2(400.\text{mL})$

$M_2 = 0.0625$ M $Al(NO_3)_3$

$[NO_3^-] = 3(.0625\text{M}) = 0.1875$ M

$1.50\text{ M} + 0.1875\text{ M} = 1.6875$ M

$\boxed{[NO_3^-]_{final} = 1.69\text{ M}}$

(#14 is optional)

14. Calculate the concentration of potassium ion in a solution that was made by mixing 100. mL of 0.200 M K_3PO_4 and 450. mL of 0.600 M $KHCO_3$. Assume volumes are additive.

Total V = 450. mL + 100. mL = 550. mL

K_3PO_4: $(.200\text{M} \times 100.\text{mL}) = M_2(550.\text{mL})$

$M_2 = 0.03636$ M K_3PO_4

$[K^+] = 3(.03636) = 0.10909$ M

$KHCO_3$:

$(.600\text{M})(450.\text{mL}) = M_2(550.\text{mL})$

$M_2 = 0.4909$ M

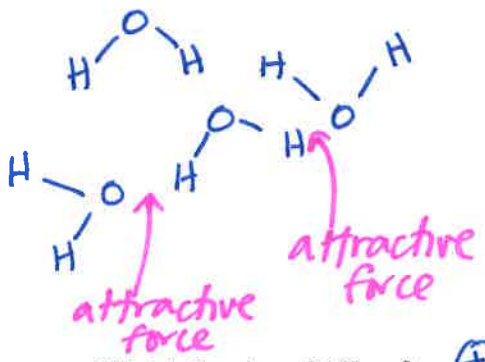
$[K^+] = 0.4909$ M

$0.10909 + 0.4909 = 0.5999 \rightarrow \boxed{[K^+]_{final} = 0.600\text{ M}}$

15. Consider the compounds LiCl and KBr, and their aqueous solutions.
When either solution forms,

a. What is the sign of $\Delta H_{solvent}$? ⊕ (endothermic)

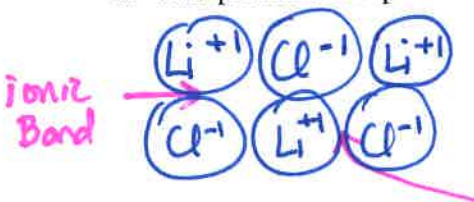
b. What process corresponds the $\Delta H_{solvent}$, and why does $\Delta H_{solvent}$ have this sign? Include a picture!



The solvent is H_2O. some of the H_2O must separate from each other to make room for the ions to dissolve. Energy is required to overcome the attractive forces ("hydrogen bonds") between H_2O molecules. since energy is required, (must be absorbed), so its endothermic.

c. What is the sign of ΔH_{solute}? ⊕ (endo)

d. What process corresponds the ΔH_{solute}, and why does ΔH_{solute} have this sign? Include a picture!



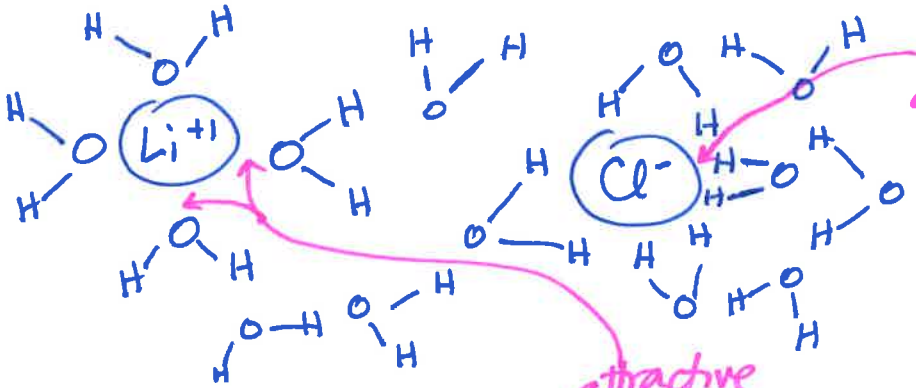
(or draw KBr)

The solute is LiCl (or KBr) energy is required to separate the ⊕ and ⊖ ions from each other, since the oppositely charged ions are attracted to each other. (or: energy is needed to break the ionic bonds.)

e. What is the sign of ΔH_{mixing}? ⊖ (exo)

f. What process corresponds the ΔH_{mixing}, and why does ΔH_{mixing} have this sign? Include a picture!

In mixing, the solute and solvent mix together, so the attractive forces can occur between solute & solvent particles.



Since the H_2O and ions are attracted to each other, energy is released as they become closer to each other.

LiCl has a $\Delta H_{solution}$ = - 37 kJ/mole
KBr has a $\Delta H_{solution}$ = +198 kJ/mole

(called an "ion-dipole" force since H_2O is polar)

g. Based on the sign of $\Delta H_{solution}$, how do the magnitudes of $\Delta H_{solvent}$, ΔH_{solute}, and ΔH_{mix} compare in LiCl?

$|\Delta H_{mix}| > |\Delta H_{solute}| + |\Delta H_{solvent}|$

(more energy is released than absorbed, so ΔH_{soln} is negative (-37 kJ))

h. Based on the sign of $\Delta H_{solution}$, how do the magnitudes of $\Delta H_{solvent}$, ΔH_{solute}, and ΔH_{mix} compare in KBr?

$|\Delta H_{mix}| < |\Delta H_{solute}| + |\Delta H_{solvent}|$

(more energy is absorbed than released, so $\Delta H_{solution}$ is positive (+198 kJ))

16. On a hot summer day (106 °F or 40°C), the relative humidity is 32 %.

a. Calculate the vapor pressure of water in the air at these conditions.

Look up the EQM VP at 40°C : VP = 55.3 mm Hg

$(0.32)(55.3 \text{ mm Hg}) = 17.696 \text{ mm Hg} \rightarrow$ **18 mm Hg**

b. What is the Dew Point temperature, in °C, of this air? Explain your answer briefly.

20. °C (or really, between 20. °C and 21°C)

At 20.°C, the max VP = 17.54 mm Hg
At 21 °C, the max VP = 18.65 mm Hg

> so once the air cools to ≈20°C, it will have a humidity of more than 100%, so dew/precipitation will occur.

c. If the air cools from 40°C to 23°C, will a dew occur? Explain your answer briefly.

since 17.696 > 17.54

No. At 23°C, the max VP = 21.07 mm Hg

but the air only has ≈ 18 mm Hg of water vapor.

18 < 21.07 so a dew will **not** occur. still under 100% humidity.

17. In Machu Picchu, Peru (Elevation: 8040 feet above sea level), a typical air pressure would be about 0.742 atm. Determine the boiling point of water at this location!

$(0.742 \text{ atm})\left(\frac{760 \text{ mm Hg}}{1 \text{ atm}}\right) = 563.92 \text{ mm Hg}$ .or ≈ 564 mm Hg.

To boil, the H_2O must have a vapor pressure equal to the atmospheric pressure of 564 mm Hg.

From VP chart:

@ 90°C, VP = 525.8 mm Hg
@ 92°C, VP = 567.0 mm Hg
@ 94°C, VP = 610.9 mm Hg

← VP is pretty close to 564 mm Hg when @ 92°C

So **92°C** is the boiling pt (or really, like 91.8 ish but 92 is close enough)