AP Chemistry – Electrochem and Gas Laws Review Problems

1. What volume does 20.00 grams of O_2 occupy if it is at 35.00°C and 700.0 mm Hg?

→ 308 K

$20.0\text{ g } O_2 \left(\frac{1\text{ mol } O_2}{32.00\text{ g}}\right) = 0.625\text{ mol } O_2$

$PV = nRT$

$(700.0\text{ mmHg})V = (0.625\text{ mol})(62.4\ \frac{\text{L}\cdot\text{mmHg}}{\text{mol}\cdot\text{K}})(308\text{ K})$

V = 17.16 L

2. How many grams of CH_4 are present if 500. mL of it exerts a pressure of 0.90 atm at -10°C?

↳ 263 K

$PV = nRT$

$(0.90\text{ atm})(0.500\text{ L}) = n(0.0821\ \frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}})(263\text{ K})$

$n = 0.0208\text{ mol } CH_4$

$0.0208\text{ mol } CH_4 \left(\frac{16.04\text{ g}}{1\text{ mol } CH_4}\right) = $ **0.3 mol CH_4**

3. A gas has a pressure of 1.87 atm when its volume is 1.13 L. What will be the pressure in torr when the volume is changed to 500.0 mL?

$P_1V_1 = P_2V_2$

$(1.87\text{ atm})(1.13\text{ L}) = P_2(0.500\text{ L})$

$P_2 = 4.23\text{ atm}$

$4.23\text{ atm}\left(\frac{760\text{ torr}}{1\text{ atm}}\right) = $ **3210 torr**

4. Explain the following occurrences using gas laws.

a. The tires of your car go flat during winter.

↓T = slow particle movement = ↓KE collisions with container wall (elastic) = ↓V

b. The plastic cover of your TV dinner inflates when heated in the microwave.

↑T = higher particle velocity = ↑KE collisions w/ container wall (elastic = ↑V

c. Your lungs fill with air when your chest cavity expands.

↑V = infrequent collisions w/ container wall = ↓P

(air flows from high P outside to low P inside lungs)

0.124 g

5. ~~5.00g~~ of O_2 gas must be collected for during an experiment.

a. If the gas is collected in a 25mL manometer bulb at 25°C, what Δh would signify the target amount of gas was collected?

$$0.124\ g\ O_2 \left(\frac{1\ mol}{32\ g}\right) = 0.00388\ mol\ O_2$$

$$PV = nRT$$

$$P(0.025\ L) = (0.00388\ mol)\left(0.0821\ \frac{L\cdot atm}{mol\cdot K}\right)(298\ K)$$

$$P = 3.80\ atm = \boxed{2900\ mm\ Hg}$$

b. If the reaction performed is the decomposition of hydrogen peroxide, what volume of 0.15M hydrogen peroxide would be needed to create the target amount of gas?

$$2H_2O_2\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g)$$

$$0.00388\ mol\ O_2 \left(\frac{2\ mol\ H_2O_2}{1\ mol\ O_2}\right)\left(\frac{1\ L}{0.15\ mol\ H_2O_2}\right) = 0.0517\ L = \boxed{52\ mL\ H_2O_2}$$

c. The perfect amount of 0.15M hydrogen peroxide is reacted and all of the gas produced is collected in the manometer. The final pressure in the manometer bulb is 3.99 atm. Explain this observation.

P_{exp} was > P_{theor} because the reaction was performed over water (H_2O_2 (aq)), therefore vapor pressure from water must be present due to H_2O (g).

$$P_{exp} = P_{theor} + P_{H_2O}$$

6. At a deep-sea station 200. m below the surface of the Pacific Ocean, workers live in a highly pressurized environment.

a. How many liters of gas at STP must be compressed on the surface to fill the underwater environment with 2.00×10^7 L of gas at 20.0 atm if the researchers want a comfortable temperature of 25.3°C in their living quarters?

$V = 2.00 \times 10^7 L$
$P = 20.0$ atm
$T = 25.3°C = 298.3 K$
$n = ?$

$(20.0 \text{ atm})(2.00 \times 10^7 L) = n(0.0821)(298.3K)$
$n = 1.63 \times 10^7$ mol gas needed

$1.63 \times 10^7 \text{ mol gas} \left(\frac{22.4 L}{1 \text{ mol}}\right) = \boxed{3.66 \times 10^8 \text{ L gas}}$ at surface

b. If the glass seal of the research station can withstand a pressure difference of 10.0 atm, what volume of air (at STP) could escape the facility and bubble to the surface before the walls collapse? The water pressure at 200. m is about 20.0 atm.

Loss of 10 atm allowed = ? L escaped

Inside $(10.0 \text{ atm})(2.00 \times 10^7 L) = n(0.0821)(298.3K)$
$n = 8.15 \times 10^6$ moles could be lost

$8.15 \times 10^6 \text{ mol} \left(\frac{22.4 L}{1 \text{ mol}}\right) = \boxed{1.83 \times 10^8 \text{ L gas}}$ at surface

c. Which gas, nitrogen, oxygen or argon, would be lost from the facility first if there was a leak? Provide a comparison of the rate of loss for each.

#1 = O_2 = 32 g/mol
#2 = N_2 = 28.02 g/mol
#3 = Ar = 39.95 g/mol

$\frac{r_{N_2}}{r_{O_2}} = \sqrt{\frac{m_{O_2}}{m_{N_2}}} = 1.07$ N_2 effuses 1.07 times faster than O_2

$\frac{r_{N_2}}{r_{Ar}} = \sqrt{\frac{m_{Ar}}{m_{N_2}}} = 1.19$ N_2 effuses 1.19 times faster than Ar

d. The mixture of gasses by mass is 79% N_2, 20%O_2 and 1%Ar before the leak and 70%N_2, 25%O_2 and 5%Ar after the leak. Compare the partial pressure of oxygen before (20 atm) and after (10 atm) the leak.

$79 g N_2 \left(\frac{1 \text{ mol}}{28.02 g}\right) = 2.82 \text{ mol } N_2$
$20 g O_2 \left(\frac{1 \text{ mol}}{32 g}\right) = 0.625 \text{ mol } O_2$
$1 g Ar \left(\frac{1 \text{ mol}}{39.95 g}\right) = 0.0250 \text{ mol Ar}$
3.47 Total Moles

$P_{O_2} = \left(\frac{0.625 \text{ mol}}{3.47 \text{ mol}}\right)(20 \text{ atm})$
$\boxed{3.6 \text{ atm } O_2 \text{ before leak}}$

$70 g N_2 \left(\frac{1 \text{ mol}}{28.02 g}\right) = 2.50 \text{ mol } N_2$
$25 g O_2 \left(\frac{1 \text{ mol}}{32 g}\right) = 0.781 \text{ mol } O_2$
$5 g Ar \left(\frac{1 \text{ mol}}{39.95 g}\right) = 0.125 \text{ mol Ar}$
3.41 mol total

$P_{O_2} = \left(\frac{0.781}{3.41}\right)(10 \text{ atm})$
$\boxed{2.3 \text{ atm } O_2 \text{ after leak}}$

e. The pressure exerted by water at a depth of 1 mile is approximately 115.00 atm. Does the air inside a steel hulled one-man craft provide a significant counter pressure to the water? Support with a calculation if the craft has a volume of 5000.0 L craft and is filed with enough gas to breathe for 3 days (217 mol of gas). Assume the craft equilibrates to water temperature, a chilly 7.2°C.

↳ 280.2K

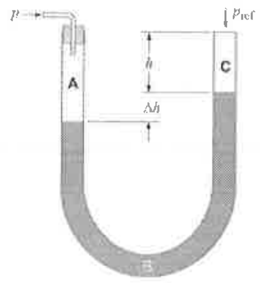
$PV = nRT$

$P(5000.0 L) = (217 \text{ mol})(0.0821)(280.2 K)$

$\boxed{P = 0.998 \text{ atm} = 1.0 \text{ atm}}$

No, it does not provide significant counter pressure against 115 atm of pressure

9.



a. What is the pressure of gas (A) in this open-ended manometer, at STP, if Δh = 65 mm?

$65\ mmHg \left(\frac{1\ atm}{760\ mmHg}\right) = 0.0855\ atm = \Delta h$

$P_{gas} = P_{atm} + \Delta h$

$= 1\ atm + 0.0855\ atm = 1.09\ atm = \boxed{1.1\ atm}$

b. If gas A is occupying 30.0 mL and the mass of the manometer increased by 0.0668 g when the gas was collected, which is the identity of gas A: CO_2, SO_2, NO, or Cl_2 ?

44.01 64.06 26.02 70.90

V = 0.0300 L

T = 273 K

P = 1.09 atm

n = ?

$(1.09\ atm)(0.0300\ L) = n(0.0821)(273\ K)$

$n = 0.00146$ mol gas

$\text{Molar Mass} = \frac{g}{mol} = \frac{0.0668\ g}{0.00146\ mol} = \boxed{45.79\ g/mol}$

closest to CO_2 molar mass of 44.01 g/mol

10. What is the molecular weight of a gas if 4.4 grams of it occupy 330 mL at a pressure of 745mmHg and a temperature of 75°C?

V = 0.330 L

P = 745 mmHg

T = 75 + 273 = 348 K

n = ?

$(745\ mmHg)(0.330\ L) = n\left(62.4\ \frac{L\cdot mmHg}{mol\cdot K}\right)(348\ K)$

$n = 0.0113$ mol

$\text{Molar Mass} = g/mol = \frac{4.4\ g}{0.0113\ mol} = \boxed{390\ g/mol}$

12. A container has 20.0 grams of N_2, 110. grams of Xe, and 36.0 grams of Ar.

a. What is the total pressure in the container if the volume is 3.00 L and the temperature is 40.0°C? (313 K)

$20\ g\ N_2 \left(\frac{1\ mol}{28.02\ g}\right) = 0.714$ mol N_2

$110\ g\ Xe \left(\frac{1\ mol}{131.29\ g}\right) = 0.838$ mol Xe

$36\ g\ Ar \left(\frac{1\ mol}{39.95\ g}\right) = 0.901$ mol Ar

Total Moles = 2.45 mol

$P_T V = n_T RT$

$P_T(3.00\ L) = (2.45\ mol)(0.0821)(313\ K)$

$\boxed{P_T = 21.0\ atm}$

b. What is the partial pressure of Xe?

$P_{Xe} = X_{Xe} P_T$

$P_{Xe} = \left(\frac{0.838\ mol\ Xe}{2.45\ mol\ total}\right)(21.0\ atm)$

$= \boxed{7.18\ atm}$

16. Which gas in each pair would deviate most from ideality and why?

a. N_2 vs. Cl_2

b. CH_2O vs. CH_4

Both non-polar

a) :N≡N: :Cl–Cl:

Cl w/ more e^- can have larger dipole moment (london dispersion)

b) δ^- O, δ^+ C, H H — Polar

H–C–H (with H above and below) — Non-Polar

Polarity of CH_2O will cause intermolecular attraction

17. Two equal balloons are inflated; one with Helium and one with CO_2. Which deflates more quickly under the same conditions and how much faster?

Helium Balloon deflates 3.32 times faster due to effusion

$$\frac{r_{He}}{r_{CO_2}} = \sqrt{\frac{m_{CO_2}}{m_{He}}} = \sqrt{\frac{44.01\ g/mol}{4.00\ g/mol}} = \boxed{3.32}$$

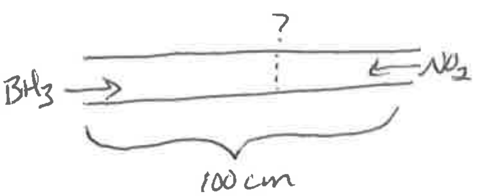
18. SO_2 diffuses 2.3 times as fast as an unknown gas. What is the molar weight of the unknown gas?

$$\frac{r_{SO_2}}{r_?} = 2.3 = \sqrt{\frac{m_?}{m_{SO_2}}}$$

$$5.29 = \frac{m_?}{64.06\ g/mol}$$

$$m_? = \boxed{340\ g/mol}$$

19. If BH_3 is put into one end of a tube marked 0 cm and NO_2 is put into the other end marked 100 cm, at what distance mark on the tube do they meet?



$$100 = x + 1.82x$$

(slow distance NO_2) (fast distance BH_3)

$$100 = 2.82x$$

x = 35.5 cm from NO_2 end
= 64.5 cm from BH_3 end

$$\frac{r_{BH_3}}{r_{NO_2}} = \sqrt{\frac{m_{NO_2}}{m_{BH_3}}} = \sqrt{\frac{46.01\ g/mol}{13.83\ g/mol}} = 1.82$$

20. A sample of F_2 diffuses 5.2 meters through a tube in 2.3 seconds. An unknown gas under identical conditions travels 3.0 meters in the same time. What is the identity of the unknown gas: HNO, HSO_2, or P_2O_3?

HNO → 31.02 g/mol; HSO_2 → 65.07 g/mol; P_2O_3 → 109.96

$$\frac{r_{F_2}}{r_?} = \frac{5.2}{3.0} = \sqrt{\frac{m_?}{m_{F_2}}}$$

$$1.73 = \sqrt{\frac{m_?}{38\ g/mol}}$$

$$3.00 = \frac{m_?}{38\ g/mol}$$

$$m_? = \boxed{114.17\ g/mol}$$

closest to mass of P_2O_3

21. Balance the following reactions.

a. $Mn^{2+} + Cu^{2+} ===> Mn^{7+} + Cu$

$2(Mn^{2+} \rightarrow Mn^{7+} + 5e^-)$

$5(Cu^{2+} + 2e^- \rightarrow Cu)$

$2Mn^{2+} + 5Cu^{2+} \rightarrow 2Mn^{7+} + 5Cu$

b. P + Cu^{2+} ===> Cu + $H_2PO_4^{1-}$ (in acidic conditions)

$2(P \rightarrow H_2PO_4^- + 5e^-)$

$5(Cu^{2+} + 2e^- \rightarrow Cu)$

$\rightarrow$ $8H_2O + 2P \rightarrow 2H_2PO_4^- + 10e^- + 12H^+$

$5Cu^{2+} + 10e^- \rightarrow 5Cu$

$8H_2O(l) + 2P(s) + 5Cu^{2+}(aq) \rightarrow 2H_2PO_4^-(aq) + 5Cu(s) + 12H^+(aq)$

c. Zn + NO_3^- ===> $Zn(OH)_4^{2-}$ + NH_3 (in basic conditions)

$4(Zn \rightarrow Zn^{2+} + 2e^-)$

$8e^- + \overset{+5}{N}O_3^- \rightarrow \overset{-3}{N}H_3$

$4Zn \rightarrow 4Zn^{2+} + 8e^-$

$\rightarrow$ $6H_2O + 8e^- + NO_3^- \rightarrow NH_3 + 9OH^-$

$6H_2O(l) + 4Zn(s) + NO_3^-(aq) \rightarrow 4Zn^{2+}(aq) + NH_3(s) + 9OH^-(aq)$

22)

1. $Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$	+ .80
2. $Hg_2^{+2}{}_{(aq)} + 2e^- \rightarrow 2Hg_{(l)}$	+ .79
3. $Sn^{+2}{}_{(aq)} + 2e^- \rightarrow Sn_{(s)}$	- .14
4. $Ni^{+2}{}_{(aq)} + 2e^- \rightarrow Ni_{(s)}$	- .25

a. Which metal in the table is most likely to spontaneously oxidize? Ni

b. Which metal in the table is most likely to spontaneously reduce? Ag

c. Which combination of half reactions would create the greatest cell potential? Ox Ni

Red Ag

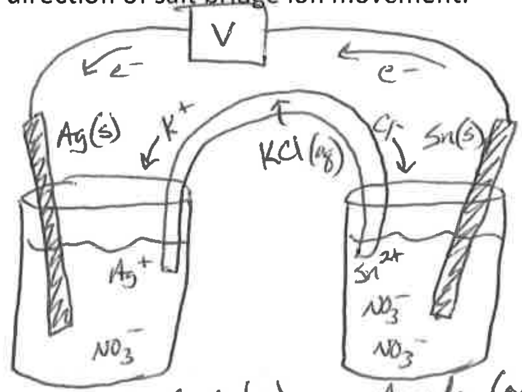
d. A cell is created with tin and silver electrodes in nitrate solutions of the same metals. Which metal electrode will gain mass and which will lose? Explain.

Ag ⇒ $E_{red} = +0.80$ likely reduced

Sn ⇒ $E_{red} = -0.14$ likely oxidized

- Ag electrode will gain mass
  $Ag^+ + e^- \rightarrow Ag(s)$
- Sn electrode will lose mass
  $Sn(s) \rightarrow Sn^{2+} + 2e^-$

e. Diagram a galvanic cell from part d. Include labels for the cathode, anode, direction of e- movement, oxidation, reduction, and direction of salt bridge ion movement.



Cathode (reduction) Anode (oxidation)

$Ag^+_{(aq)} + e^- \rightarrow Ag\,(s)$ $Sn\,(s) \rightarrow Sn^{2+}(aq) + 2e^-$

f. Which of the following would be an appropriate choice for a salt bridge solution in the diagram above? K_2SO_4, K_3PO_4, KCl. Explain your choice.

- Group 1 metals & halides* (except F⁻) are always* soluble, therefore we can guarantee no reaction will occur due to the presence of these ions (no ppt formed)
- However, even though Cl⁻ is moving away from Ag half-cell, creation of AgCl ppt is still possible. KNO_3 would be a better choice.

* unless paired w/ Ag, Hg, Pb

g. The tin electrode in the cell above is documented to have an initial mass of 35.50 g. Hypothesize a likely mass for the electrode after running for 8 hours and creating a current of 1.5 A. $Sn\,(s) \rightarrow Sn^{2+} + 2e^-$

$$8 \text{ hours} \left(\frac{60 \text{ min}}{1 \text{ hr}}\right)\left(\frac{60 \text{ sec}}{1 \text{ min}}\right) = 28{,}800 \text{ seconds}$$

$$I = \frac{q}{t} \qquad 1.5\text{ A} = \frac{q}{28{,}800 \text{ sec}}$$

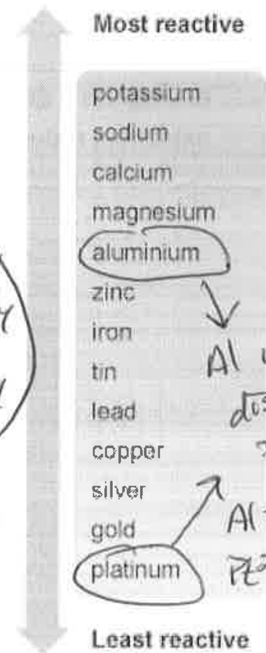
$$q = 43{,}200 \text{ coulombs}$$

$$43{,}200 \text{ coul}\left(\frac{1 \text{ mol } e^-}{96{,}485 \text{ coulombs}}\right)\left(\frac{1 \text{ mol Sn}}{2 \text{ mol } e^-}\right)\left(\frac{118.71 \text{ g}}{1 \text{ mol Sn}}\right) = 26.58 \text{ g Sn oxidized}$$

(converted into Sn^{2+})

$$\underset{\text{initial}}{35.50\text{g Sn}} - \underset{\text{lost}}{26.58\text{g Sn}} = \boxed{\underset{\text{left}}{8.92 \text{ g Sn}}}$$

23) a. Use the half-reactions and the reactivity series provided to write a balanced equation for the reaction that would occur if aluminum is placed into a platinum nitrate solution. Explain your reasoning.



Half – Reaction	E° (V)	
$[PtCl_4]^{2-}(aq) + 2e^- \longrightarrow Pt(s) + 4Cl^-(aq)$	+ .72	$Pt^{2+} \rightarrow Pt$ likely
$Al^{+3}_{(aq)} + 3e^- \longrightarrow Al_{(s)}$	- 1.66	$Al \rightarrow Al^{3+}$ likely

Al will displace Pt

$Al \rightarrow Al^{3+}$

$Pt^{2+} \rightarrow Pt$

Full: $2Al(s) + 3Pt(NO_3)_2(aq) \rightarrow 2Al(NO_3)_3(aq) + 3Pt(s)$

Net Ionic: $2Al(s) + 3Pt^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Pt(s)$

b. If a piece of aluminum is placed into the platinum (II) nitrate solution, will it be plated by platinum? If yes, explain why. If no, explain what must be done to cause plating to occur in the platinum (II) nitrate cell.

Pt = likely reduced ($E_{red} = +0.72$) = likely forms Pt (s) (re plates)

Al = likely oxidized ($E_{red} = -1.66$) = likely forms $Al^{3+}(aq)$ (ie dissolves into solution)

c. Calculate the following for the plating of 25.0 g of platinum onto ~~the aluminum electrode.~~ an electrode

1) Coulombs of electricity necessary to deposit the platinum from the $Pt(NO_3)_2$.

$$25.0\,g\ Pt \left(\frac{1\ mol\ Pt}{195.08\ g}\right)\left(\frac{2\ mol\ e^-}{1\ mol\ Pt}\right)\left(\frac{96{,}485\ coulombs}{1\ mol\ e^-}\right) = \boxed{24{,}700\ coulombs}$$

2) How many minutes will take to plate out the silver using a current of 20.0A.

$$I = \frac{q}{t}$$

$$20.0\ A = \frac{24{,}700\ coulombs}{t}$$

$$t = 1236\ sec\left(\frac{1\ min}{60\ sec}\right) = \boxed{20.6\ minutes}$$