## Recitation Worksheet (Optional Extra Practice)

Name: Key | UGA ID:

**Textbook:**
Chemistry & Chemical Reactivity
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**Instructions:**
- This recitation worksheet is optional extra practice for Ch. 10.7-10.8.
- You **do not** need to submit it to Gradescope.
- The answer key has been posted with this worksheet to eLC.
- A periodic table and formula sheet are attached to the end of this worksheet.

1. Consider a number of gases provided below. Which of the following will diffuse the slowest at 85 °C?

B

A. $F_2$ → 38.00 g/mol
B. Xe → 131.29 g/mol
C. $O_2$ → 32.00 g/mol
D. Ar → 39.95 g/mol
E. Ne → 20.18 g/mol

→ MW = 44.01 g/mol

2. The effusion rate of carbon dioxide was measured at 70 °C. Afterwards, the effusion rate of a number of gases were collected at the same temperature. Which of the following gases provided below had the closest rate of effusion to carbon dioxide?

C

A. Ar → 39.95 g/mol
B. Xe → 131.29 g/mol
C. $C_3H_8$ → 44.11 g/mol
D. $O_2$ → 32.00 g/mol
E. He → 4.00 g/mol
F. Ne → 20.18 g/mol

→ $N_2$ = 28.02 g/mol

3. An experiment was conducted in which the ratio of the rates of effusion of nitrogen gas to another diatomic gas was 2.3881. What is the identity of the unknown gas? Write the chemical formula in the box below.

$Br_2$

$$2.3881 = \frac{\sqrt{M_2}}{\sqrt{28.02\ g/mol}} \rightarrow M_2 = 159.79867\ g/mol$$

$$M_2 = 159.79867\ g/mol \,/\, 2 = 79.899\ g/mol$$

4. Many reactions done in the laboratory are air-sensitive and require inert gases such as $N_2$ or Ar to prevent unwanted reactivity. Although only one gas is typically chosen in any given scenario, consider a situation in which a scientist introduces 3.50 mol of $N_2$ and 3.50 mol of Ar into a closed container. If a pinhole leak is introduced at a constant temperature, which of the following statements are **true** after a period of time? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

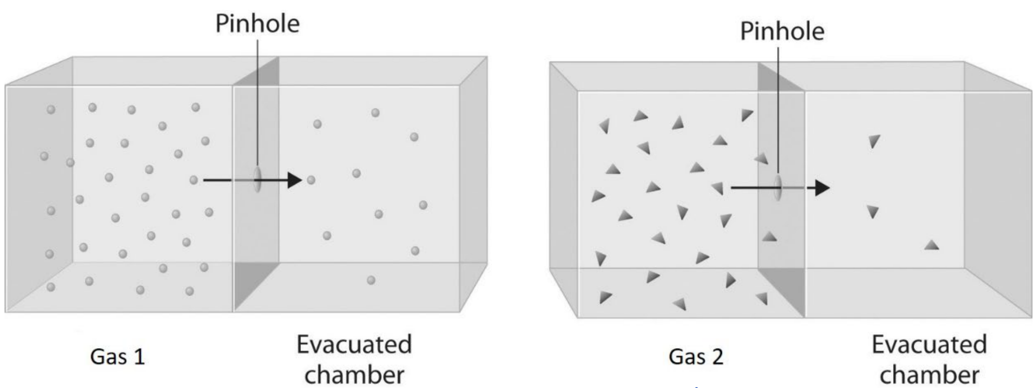
BE

$N_2$ = 28.02 g/mol → effuses faster ↓ less $N_2$ in container ↓ lower $P_{N_2}$

Ar = 39.95 g/mol

A. The partial pressure of both gases will increase
B. The partial pressure of both gases will decrease
C. The partial pressure of both gases will remain the same
D. The partial pressure of $N_2$ will be higher than the partial pressure of Ar
E. The partial pressure of Ar will be higher than the partial pressure of $N_2$

5. In the image below, both gases have been allowed to effuse for the same amount of time. Which gas has the **higher** molar mass?




↳ lower effusion rate

B

A. Gas 1
B. Gas 2
C. Both gases have the same molar mass
D. It's impossible to tell based on the image

6. Two gases (1.0 atm of gas A and 0.5 atm of gas B) are placed on either side of a partition in a chamber. When the partition is removed, it takes 5.6 minutes for the two gases to fully mix. What is true about these gases? ↳ diffusion

F

A. They have the same molar mass
B. Gas A has a higher molar mass
C. Gas B has a higher molar mass
D. Gas A effused faster
E. Gas B effused faster
F. This is diffusion, so molar mass cannot be compared
G. More than one of the above is true

7. Two different hypothetical gases and their van der Waals correction factors are provided in the table below. Based on this information, which gas's *volume* is expected to be the *least* similar to an ideal gas?

volume correction

| Gas | *a* ((L$^2$·atm)/mol$^2$) | *b* (L/mol) |
|---|---|---|
| Gas A | 5.35 | 12.50 |
| Gas B | 104.34 | 1.12 |

A

A. Gas A, because it has the largest "*b*" correction factor
B. Gas B, because it has the largest "*a*" correction factor
C. Gas A, because the average of both its correction factors (8.93) is smaller than the average of Gas B's correction factors
D. Gas B, because the average of both its correction factors (52.7) is greater than the average of Gas A's correction factors
E. It is inconclusive because units of volume are present in both correction factors

8. Answer the following questions using the table below of five different hypothetical gases and their van der Waals correction factors.

| Gas | a ($(L^2 \cdot atm)/mol^2$) | b (L/mol) |
|---|---|---|
| Gas A | 12.391 | 0.819 |
| Gas B | 13.711 | 0.901 |
| Gas C | 1.341 | 0.100 |
| Gas D | 4.981 | 0.244 |

(a) Which gas will behave the most nonideally?

B

A. Gas A
B. Gas B → largest correction factor
C. Gas C
D. Gas D

(b) Which gas would have the most similar volume to an ideal gas?

C

A. Gas A
B. Gas B
C. Gas C → smallest "b" correction factor
D. Gas D

(c) Which gas would have the least similar pressure to an ideal gas?

B

A. Gas A
B. Gas B → largest "a" correction factor
C. Gas C
D. Gas D

9. Which of the following statements are true regarding the van der Waals equation? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

BC

A. The van der Waals constant "*a*" corrects for temperature
B. The van der Waals constant "*b*" corrects for volume
C. The smaller the van der Waals constant "*a*", the more ideally the gas behaves
D. The larger the van der Waals constant "*b*", the more ideally the gas behaves
E. None of the above are true

10. A researcher roughly calculates the expected pressure and volume of a gas using the ideal gas law. When they measure the volume, it is exactly the same as calculated. When they measure pressure, it is very different from their calculation. What could explain this finding?

A

A. The gas has a large "*a*" correction factor
B. The gas is at a very high temperature
C. The gas has a large "*b*" correction factor
D. The gas is at a very low pressure
E. More than one of the above could explain the discrepancy
F. None of the above would explain the discrepancy

11. Consider an unknown gas that is placed in various temperature and pressure conditions provided below. Under which set of conditions will the unknown gas behave most ideally?

B

High temp.
Low pressure

A. Pressure: 0.1 atm; temperature: 273 K
B. Pressure: 0.1 atm; temperature: 350 K
C. Pressure: 1 atm; temperature: 273 K (STP)
D. Pressure: 1 atm; temperature: 350 K
E. The identity of the gas is required to determine what conditions will affect ideal behavior

**Additional Practice Questions:**

1. Most helium in nature is the $^4He$ isotope, with a precise molar mass of 4.00260 g/mol. The $^3He$ isotope (molar mass = 3.01603 g/mol) is used in ultracold systems, and is separated from bulk helium by effusion. What is the relative rate (ratio) of effusion of $^3He$ relative to $^4He$?

C

$$\frac{^3He}{^4He} = \frac{\sqrt{4.00260\ g/mol}}{\sqrt{3.01603\ g/mol}} = 1.15200$$

A. 0.753518
B. 0.868054
C. 1.15200
D. 1.32711
E. 1.76122

2. Which of the following gases would diffuse at the slowest rate?

E

A. $H_2$
B. $Cl_2$
C. $O_2$
D. $CH_3Cl$
E. $CF_4$ largest molar mass

3. If nitrogen gas ($N_2$) effuses at a rate of 4.58 L/min under a certain set of conditions, what would the rate of effusion (L/min) of neon gas be under the same conditions? Report your answer in **standard notation**. (Ne)

5.40 L/min

$$\frac{4.58\ L/min}{x} = \sqrt{\frac{20.18\ g/mol}{28.02\ g/mol}}$$

→ 44.01 g/mol

4. An unknown gas effuses from a container 1.66 times more rapidly than $CO_2$. Which of the following is the most reasonable guess of the identity of the unknown gas?

| |
|---|
| A |

$$\frac{1.66}{1} = \sqrt{\frac{44.01\ g/mol}{x}} \rightarrow x = 15.971\ g/mol$$

A. $CH_4$ → 16.05 g/mol
B. Sb
C. $O_2$
D. $CCl_2F_2$

→ MM = 14.03 g/mol

5. An unknown gas has an empirical formula of $CH_2$. The unknown gas and chlorine gas ($Cl_2$) are mixed in a container and allowed to effuse. Exactly 232 mL of chlorine gas effuses in 10 seconds under these conditions. If 301 mL of the unknown gas effuses in this same time period, what is the molecular formula of the unknown gas?

| |
|---|
| $C_3H_6$ |

$$\frac{232\ mL}{301\ mL} = \sqrt{\frac{x}{70.90\ g/mol}} \rightarrow 42.1200\ g/mol$$

$$\frac{42.1200\ g/mol}{14.03\ g/mol} = \sim 3 \rightarrow C_3H_6$$

6. A 2.278 × $10^{-4}$ mol sample of an unidentified gaseous substance effuses through a tiny hole in 95.70 s. Under identical conditions, 1.738 × $10^{-4}$ mol of argon gas (molar mass = 39.95 g/mol) takes 81.60 s to effuse. What is the molar mass of the unidentified substance?

C

$$\text{rate (unknown)} = \frac{2.278 \times 10^{-4}\ \text{mol}}{95.70\ \text{s}} = 2.380355 \times 10^{-6}\ \text{mol/s}$$

$$\text{rate (Argon)} = \frac{1.738 \times 10^{-4}\ \text{mol}}{81.60\ \text{s}} = 2.129901 \times 10^{-6}\ \text{mol/s}$$

$$\frac{2.380355 \times 10^{-6}\ \text{mol/s}}{2.129901 \times 10^{-6}\ \text{mol/s}} = \sqrt{\frac{39.95\ \text{g/mol}}{M_{unknown}}}$$

$$M_{unknown} = 31.985449\ \text{g/mol}$$

A. 23.25 g/mol
B. 29.05 g/mol
C. 31.99 g/mol
D. 49.90 g/mol

7. A real gas will behave *most* like an ideal gas under which of the following conditions?

B

High T, low P

A. 1 atm and 73 K
B. 1 atm and 550 K
C. 10 atm and 73 K
D. 10 atm and 550 K

# Periodic Table of the Elements

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H 1.01 | | | | | | | | | | | | | | | | | 2 He 4.00 |
| 3 Li 6.94 | 4 Be 9.01 | | | | | | | | | | | 5 B 10.81 | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.00 | 10 Ne 20.18 |
| 11 Na 22.99 | 12 Mg 24.31 | | | | | | | | | | | 13 Al 26.98 | 14 Si 28.09 | 15 P 30.97 | 16 S 32.06 | 17 Cl 35.45 | 18 Ar 39.95 |
| 19 K 39.10 | 20 Ca 40.08 | 21 Sc 44.96 | 22 Ti 47.87 | 23 V 50.94 | 24 Cr 52.00 | 25 Mn 54.94 | 26 Fe 55.85 | 27 Co 58.93 | 28 Ni 58.69 | 29 Cu 63.55 | 30 Zn 65.38 | 31 Ga 69.72 | 32 Ge 72.63 | 33 As 74.92 | 34 Se 78.97 | 35 Br 79.90 | 36 Kr 83.80 |
| 37 Rb 85.47 | 38 Sr 87.62 | 39 Y 88.91 | 40 Zr 91.22 | 41 Nb 92.91 | 42 Mo 95.95 | 43 Tc [97] | 44 Ru 101.07 | 45 Rh 102.91 | 46 Pd 106.42 | 47 Ag 107.87 | 48 Cd 112.41 | 49 In 114.82 | 50 Sn 118.71 | 51 Sb 121.76 | 52 Te 127.60 | 53 I 126.90 | 54 Xe 131.29 |
| 37 Cs 132.91 | 56 Ba 137.33 | | 72 Hf 178.49 | 73 Ta 180.95 | 74 W 183.84 | 75 Re 186.21 | 76 Os 190.23 | 77 Ir 192.22 | 78 Pt 195.08 | 79 Au 196.97 | 80 Hg 200.59 | 81 Tl 204.38 | 82 Pb 207.2 | 83 Bi 208.98 | 84 Po [209] | 85 At [210] | 86 Rn [222] |
| 87 Fr [223] | 88 Ra [226] | | 104 Rf [267] | 105 Db [268] | 106 Sg [269] | 107 Bh [270] | 108 Hs [269] | 109 Mt [277] | 110 Ds [281] | 111 Rg [282] | 112 Cn [285] | 113 Nh [286] | 114 Fl [290] | 115 Mc [290] | 116 Lv [293] | 117 Ts [294] | 118 Og [294] |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 La 138.91 | 58 Ce 140.12 | 59 Pr 140.91 | 60 Nd 144.24 | 61 Pm [145] | 62 Sm 150.36 | 63 Eu 151.96 | 64 Gd 157.25 | 65 Tb 158.93 | 66 Dy 162.50 | 67 Ho 164.93 | 68 Er 167.26 | 69 Tm 168.93 | 70 Yb 173.05 | 71 Lu 174.97 |
| 89 Ac [227] | 90 Th 232.04 | 91 Pa 231.04 | 92 U 238.03 | 93 Np [237] | 94 Pu [244] | 95 Am [243] | 96 Cm [247] | 97 Bk [247] | 98 Cf [251] | 99 Es [252] | 100 Fm [257] | 101 Md [258] | 102 No [259] | 103 Lr [262] |

# Formula Sheet

**Length**
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = $1 \times 10^{-10}$ meter

**Energy**
1 joule = 1 $kg \cdot m^2/s^2$
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

**Pressure**
1 pascal = 1 $N/m^3$ = 1 $kg/m \cdot s^2$
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 $lb/in^2$
1 bar = $1 \times 10^5$ Pa (exactly)

**Temperature**
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

**Mass**
1 kg = 2.205 lbs

**Volume**
1 mL = 1 $cm^3$ = 1 cc

**Constants**
c = $2.998 \times 10^8$ m/sec
h = $6.626 \times 10^{-34}$ J·sec
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: $9.109 \text{ x } 10^{-31}$ kg
Mass of a proton: $1.673 \text{ x } 10^{-27}$ kg
RH = $2.18 \text{ x } 10^{-18}$ J
Specific heat of water = 4.184 J/g·K
Avogadro's number: $6.022 \times 10^{23}$
F = 96485 J/(V·mol $e^-$)
$K_w = 1.0 \times 10^{-14}$ at 25 °C
$k_b = 1.381 \times 10^{-23}$ J/K

**Equations**
$(P + a(n^2/V^2))\cdot(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT

$$KE = \frac{3}{2}RT$$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ of\ effusion\ A}{Rate\ of\ effusion\ B} = \sqrt{\frac{MW_B}{MW_A}}$$

$$\Delta E = -2.18 \times 10^{-18} J(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$C_g = kP_g$
$P_{solution} = P_{solvent}\, X_{solvent}$
$P_{solution} = \sum P_j = \sum P_j X_j$
$\pi = MRTi$

**Thermodynamic and Electrochemistry**
$S = k_b \times \ln(W)$
$\Delta S = q_{rev}/T$
$\Delta G = \Delta G° + RT \cdot \ln Q$
R=8.314 J/mol.K
$\Delta G° = -RT \cdot \ln K$
$\Delta G = -nFE_{cell}$
$E°_{cell} = RT/nF \ln K$
$E°_{cell} = (0.0257/n) \ln K = (0.0592/n) \log K$
$E_{cell} = E°_{cell} - (RT/nF) \ln Q$
$E_{cell} = E°_{cell} - (0.0257/n) \ln Q$
Electrolysis: Q (total charge) = I × t = n × F

**Integrated Rate Laws & half-life**

$$\ln\frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$ln\frac{k_2}{k_1} = -\frac{E_a}{R}(\frac{1}{T_2} - \frac{1}{T_1})$$

**Equilibrium and Acid / Base**
$K_P = K_c \times (RT)^{\Delta n}$

$$ln\frac{K_2}{K_1} = \frac{\Delta H^{\circ}_{rxn}}{R}(\frac{1}{T_1} - \frac{1}{T_2})$$