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signature

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| 1                  |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    | 18                 |                    |                    |                    |                    |                    |                    |
| 1<br>H<br>1.008    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    | 2<br>He<br>4.003   |                    |                    |                    |                    |                    |                    |
| 3<br>Li<br>6.941   | 4<br>Be<br>9.012   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    | 5<br>B<br>10.81    | 6<br>C<br>12.01    | 7<br>N<br>14.01    | 8<br>O<br>16.00    | 9<br>F<br>19.00    | 10<br>Ne<br>20.18  |
| 11<br>Na<br>22.99  | 12<br>Mg<br>24.31  |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    | 13<br>Al<br>26.98  | 14<br>Si<br>28.09  | 15<br>P<br>30.97   | 16<br>S<br>32.07   | 17<br>Cl<br>35.45  | 18<br>Ar<br>39.95  |
| 19<br>K<br>39.10   | 20<br>Ca<br>40.08  | 21<br>Sc<br>44.96  | 22<br>Ti<br>47.87  | 23<br>V<br>50.94   | 24<br>Cr<br>52.00  | 25<br>Mn<br>54.94  | 26<br>Fe<br>55.85  | 27<br>Co<br>58.93  | 28<br>Ni<br>58.69  | 29<br>Cu<br>63.55  | 30<br>Zn<br>65.38  | 31<br>Ga<br>69.72  | 32<br>Ge<br>72.64  | 33<br>As<br>74.92  | 34<br>Se<br>78.96  | 35<br>Br<br>79.90  | 36<br>Kr<br>83.80  |
| 37<br>Rb<br>85.47  | 38<br>Sr<br>87.62  | 39<br>Y<br>88.91   | 40<br>Zr<br>91.22  | 41<br>Nb<br>92.91  | 42<br>Mo<br>95.94  | 43<br>Tc<br>(98)   | 44<br>Ru<br>101.07 | 45<br>Rh<br>102.91 | 46<br>Pd<br>106.42 | 47<br>Ag<br>107.87 | 48<br>Cd<br>112.41 | 49<br>In<br>114.82 | 50<br>Sn<br>118.71 | 51<br>Sb<br>121.76 | 52<br>Te<br>127.60 | 53<br>I<br>126.90  | 54<br>Xe<br>131.29 |
| 55<br>Cs<br>132.91 | 56<br>Ba<br>137.33 | 57<br>La<br>138.91 | 72<br>Hf<br>178.49 | 73<br>Ta<br>180.95 | 74<br>W<br>183.84  | 75<br>Re<br>186.21 | 76<br>Os<br>190.23 | 77<br>Ir<br>192.22 | 78<br>Pt<br>195.08 | 79<br>Au<br>196.97 | 80<br>Hg<br>200.59 | 81<br>Tl<br>204.38 | 82<br>Pb<br>207.20 | 83<br>Bi<br>208.98 | 84<br>Po<br>(209)  | 85<br>At<br>(210)  | 86<br>Rn<br>(222)  |
| 87<br>Fr<br>(223)  | 88<br>Ra<br>(226)  | 89<br>Ac<br>(227)  | 104<br>Rf<br>(267) | 105<br>Db<br>(268) | 106<br>Sg<br>(269) | 107<br>Bh<br>(270) | 108<br>Hs<br>(270) | 109<br>Mt<br>(278) | 110<br>Ds<br>(281) | 111<br>Rg<br>(282) | 112<br>Cn<br>(285) | 113<br>Nh<br>(286) | 114<br>Fl<br>(289) | 115<br>Mc<br>(290) | 116<br>Lv<br>(293) | 117<br>Ts<br>(294) | 118<br>Og<br>(294) |

|                    |                    |                    |                   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |
|--------------------|--------------------|--------------------|-------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| 58<br>Ce<br>140.12 | 59<br>Pr<br>140.91 | 60<br>Nd<br>144.24 | 61<br>Pm<br>(145) | 62<br>Sm<br>150.36 | 63<br>Eu<br>151.96 | 64<br>Gd<br>157.25 | 65<br>Tb<br>158.93 | 66<br>Dy<br>162.50 | 67<br>Ho<br>164.93 | 68<br>Er<br>167.26 | 69<br>Tm<br>168.93 | 70<br>Yb<br>173.04 | 71<br>Lu<br>174.97 |
| 90<br>Th<br>232.04 | 91<br>Pa<br>231.04 | 92<br>U<br>238.03  | 93<br>Np<br>(237) | 94<br>Pu<br>(244)  | 95<br>Am<br>(243)  | 96<br>Cm<br>(247)  | 97<br>Bk<br>(247)  | 98<br>Cf<br>(251)  | 99<br>Es<br>(252)  | 100<br>Fm<br>(257) | 101<br>Md<br>(258) | 102<br>No<br>(259) | 103<br>Lr<br>(266) |

constants

$R = 0.08206 \text{ L atm/mol K}$

$R = 0.08314 \text{ L bar/mol K}$

$R = 62.36 \text{ L Torr/mol K}$

$R = 8.314 \text{ L kPa/mol K}$

$R = 8.314 \text{ J/mol K}$

$N_A = 6.022 \times 10^{23} / \text{mol}$

conversions

$1 \text{ atm} = 760 \text{ torr}$

$1 \text{ atm} = 14.7 \text{ psi}$

$1 \text{ atm} = 101325 \text{ Pa}$

$1 \text{ atm} = 1.01325 \text{ bar}$

$1 \text{ bar} = 10^5 \text{ Pa}$

$^{\circ}\text{F} = ^{\circ}\text{C}(1.8) + 32$

$\text{K} = ^{\circ}\text{C} + 273.15$

conversions

$1 \text{ in} = 2.54 \text{ cm}$

$1 \text{ ft} = 12 \text{ in}$

$1 \text{ yd} = 3 \text{ ft}$

$1 \text{ mi} = 5280 \text{ ft}$

$1 \text{ lb} = 453.6 \text{ g}$

$1 \text{ ton} = 2000 \text{ lbs}$

$1 \text{ tonne} = 1000 \text{ kg}$

$1 \text{ gal} = 3.785 \text{ L}$

$1 \text{ gal} = 231 \text{ in}^3$

$1 \text{ gal} = 128 \text{ fl oz}$

$1 \text{ fl oz} = 29.57 \text{ mL}$

$1 \text{ Troy oz} = 31.104 \text{ g}$

water data

$C_{s,\text{ice}} = 2.09 \text{ J/g } ^{\circ}\text{C}$

$C_{s,\text{water}} = 4.184 \text{ J/g } ^{\circ}\text{C}$

$C_{s,\text{steam}} = 2.03 \text{ J/g } ^{\circ}\text{C}$

$\rho_{\text{water}} = 1.00 \text{ g/mL}$

$\rho_{\text{ice}} = 0.9167 \text{ g/mL}$

$\rho_{\text{seawater}} = 1.024 \text{ g/mL}$

$\Delta H_{\text{fus}} = 334 \text{ J/g}$

$\Delta H_{\text{vap}} = 2260 \text{ J/g}$

$K_w = 1.0 \times 10^{-14}$

This exam should have exactly 20 questions. Each question is equally weighted at 5 points each. You will enter your answer choices on the virtual bubbleseet after you have finished. Your score is based on what you submit on the virtual bubblesheet and not what is circled on the exam.

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1. Consider a Maxwell-Boltzmann distribution plot of gas velocities vs number of particles (the classic plot). Assuming all the gases listed are at the same temperature, which one will have the broadest distribution of velocities in a given container?

- a. Ar
- b. SF<sub>6</sub>
- c. Kr
- d. Xe
- e. HBr

**Explanation:** The lightest gas will have the greatest range of velocities - the distribution is broader. The lightest gas listed is argon, Ar, at 40 g/mol.

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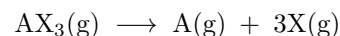
2. A 4.10 gram sample of gas was collected in a 1.50 L container at 295 K and 600 Torr. Which of these molecules listed below could be the identity of the gas sample?

- a. Kr
- b. Ar
- c. C<sub>3</sub>H<sub>8</sub>
- d. H<sub>2</sub>
- e. Cl<sub>2</sub>
- f. O<sub>2</sub>

**Explanation:** Get moles via IGL:  $n = PV/RT = 600(1.5)/(62.36(295)) = 0.0489$  mol. MWt = mass/mol =  $4.10/0.0489 = 83.8$  g/mol which is Kr.

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3. A sample of 3 moles of AX<sub>3</sub> fully decomposes according to the equation:



If the resulting gases have a total pressure of 488 Torr, what is the partial pressure of X in the final system?

- a. 390 torr
- b. 244 torr
- c. 325 torr
- d. 122 torr
- e. 366 torr
- f. 293 torr

**Explanation:** The products will form in 1/4 and 3/4 mole fractions of the total. Gas X is 3/4 of the total of 488 which is 366.

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4. Comparing a substance in its gas phase at 1 atm to its liquid phase at 1 atm, which best describes the relationship of the liquid density ( $\rho_{\text{liq}}$ ) to the gas density ( $\rho_{\text{gas}}$ )?

- a.  $\rho_{\text{liq}}$  is 1000× greater than  $\rho_{\text{gas}}$
- b.  $\rho_{\text{liq}}$  is 10<sup>6</sup>× greater than  $\rho_{\text{gas}}$
- c.  $\rho_{\text{liq}}$  is 100× greater than  $\rho_{\text{gas}}$
- d.  $\rho_{\text{liq}}$  is 10× greater than  $\rho_{\text{gas}}$

**Explanation:** it's 1000× for liquid vs gas densities... solids too for that matter

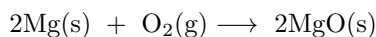
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5. A balloon was filled with 1 L of nitrogen gas and 1 L of helium, and over the next two days the balloon shrinks as the gas molecules inside escape through pores in the balloon wall. Which best describes the mole fraction of nitrogen in the balloon two days later?

- a.  $X_{\text{N}_2} = 0.5$
- b.  $X_{\text{N}_2} < 0.5$
- c.  $X_{\text{N}_2} > 0.5$
- d. You need to know the temperature to be able to answer this question.

**Explanation:** helium is much smaller than nitrogen which means it will effuse much faster which means the helium leaves the balloon faster, leaving behind a larger mole fraction of nitrogen, therefore the mole fraction of  $\text{N}_2$  is greater than 0.5 now.

6. If you have 3 moles of Mg and 3 moles of oxygen gas placed in a closed container, what is in the container after the reaction has run to completion?



- a. Mg and MgO
- b. Mg,  $\text{O}_2$ , and MgO
- c. MgO only
- d.  $\text{O}_2$  and MgO

**Explanation:** Mg is limiting. It all reacts and makes 3 mol of MgO. This rxn only uses 1.5 mol of the oxygen, so it is leftover. Therefore both MgO and  $\text{O}_2$  are leftover.

7. What is the molar mass of  $\text{C}_{14}\text{H}_8\text{F}_2$ ?

- a. 214.2 g/mol
- b. 232.3 g/mol
- c. 218.1 g/mol
- d. 226.2 g/mol
- e. 195.2 g/mol

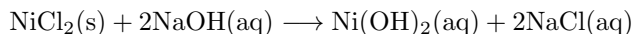
**Explanation:** Multiply the molar mass of carbon by 14 carbon atoms ( $12.01 \text{ g/mol} \times 14$ ) Repeat with  $1.008 \text{ g/mol} \times 8$  hydrogen and  $19.00 \text{ g/mol} \times 2$  fluorine)

8. You have three gases:  $\text{H}_2$ ,  $\text{F}_2$ , and  $\text{Cl}_2$ . To predict which one would have the highest van der Waals “*b*” value, you would compare:

- a. their intermolecular attractions
- b. their molar masses
- c. their pressures
- d. their temperatures

**Explanation:** *b* scales with size which matches up with molar masses

9. What mass of NaOH is required to produce 139 g  $\text{Ni(OH)}_2$  according to the following reaction? (answer to nearest whole number)



- a. 120 g NaOH
- b. 160 g NaOH
- c. 147 g NaOH
- d. 60 g NaOH
- e. 96 g NaOH

**Explanation:** 92.7 g/mol is MWt for  $\text{Ni(OH)}_2$ . So  $139/92.7 = 1.50$  mol. To go with that you’ll need  $1.5(2/1) = 3$  mol of NaOH.  $3(40) = 120$  g

10. After finishing a whole 2.1 L bottle of Diet Coke, you leave the bottle sitting on the counter for a while and then put the lid back on, sealing it shut. How many moles of gas are in the bottle if the temperature is  $25^\circ\text{C}$  and the pressure is 1.0 atm?

- a. 0.00085 mol
- b. 0.086 mol
- c. 0.094 mol
- d. 0.12 mol
- e. 0.019 mol
- f. 22 mol

**Explanation:**  $n = PV/RT = 2.1(1)/0.08206/298.15 = 0.086$  mol

11. The average speed of a gas at 350 K is 360 m/s. What will the speed be of that gas when heated up to 896 K ?

- a. 576 m/s
- b. 922 m/s
- c. 720 m/s
- d. 600 m/s
- e. 540 m/s

**Explanation:** Use the following ratio:  $\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$ , so

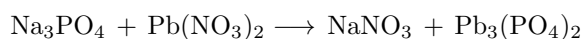
$$\frac{v_2}{360} = \sqrt{\frac{896}{350}} = 1.6 \quad v_2 = 360(1.6) = 576$$

12. Scooby the (helium) balloon dog has a volume of 5.28 L at 25.0 °C and 1.00 atm pressure. If Scooby is dropped into liquid nitrogen at -195.8 °C, what will Scooby's new volume be (still at 1 atm pressure)?

- a. 0.68 L
- b. 1.37 L
- c. 2.14 L
- d. 1.18 L
- e. 3.46 L

**Explanation:** Charles Law:  $V_2 = V_1(T_2/T_1) = 5.28 \text{ L}(77.35/298.15) = 1.37 \text{ L}$ .

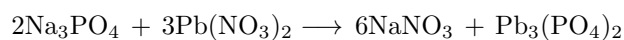
13. Properly balance the following chemical equation:



What is the sum of the coefficients after balancing?

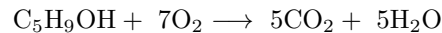
- a. 15
- b. 12
- c. 13
- d. 11
- e. 9

**Explanation:** The coefficients are as follows:



Therefore, when summing them:  $2 + 3 + 6 + 1 = 12$

14. Cyclopentanol burns according to the following equation:



Now we react 3.16 mols of  $\text{C}_5\text{H}_9\text{OH}$  with 20.3 mol of oxygen. Assuming the reaction goes to completion, how many moles of  $\text{H}_2\text{O}$  are produced ?

- a. 20.4 mol
- b. 12.5 mol
- c. 18.6 mol
- d. 14.5 mol
- e. 15.8 mol

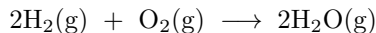
**Explanation:** You can run 3.16 mol of rxn with 3.16 mol of cyclopentanol (1:1). You can run 2.90 mol of rxn with 20.3 mol oxygen (1:7). The oxygen is limiting then. Take the 2.90 mol rxn and multiply by 5 mol water per rxn and get 14.5 mol water.

15. You have three gas samples. Rank them from lowest  $v_{\text{rms}}$  to highest  $v_{\text{rms}}$  (slowest to fastest).

- a. Ar at 600 < He at 300 < He at 600
- b. He at 300 < He at 600 < Ar at 600
- c. He at 600 < Ar at 600 < He at 300
- d. He at 300 < Ar at 600 < He at 600
- e. He at 600 < He at 300 < Ar at 600
- f. Ar at 600 < He at 600 < He at 300

**Explanation:** smaller molecules go faster... higher T molecules go faster

16. Consider the following reaction to make water vapor (temperature is high enough that water is in gas state).



If 0.642 mol  $\text{H}_2$  and 0.642 mol  $\text{O}_2$  are allowed to react completely, what volume of water vapor would be produced if the temperature is 425 K and pressure is 1.22 bar?

- a. 18.2 L
- b. 19.1 L
- c. 18.6 L
- d. 17.8 L
- e. 37.2 L

**Explanation:** Hydrogen is limiting reactant and makes 0.642 mol water vapor. Now use IGL to get volume:  $V = nRT/P = 0.642(0.08314)425/1.22 = 18.6$  L of water vapor. Note: If you want to use 0.08206 for  $R$ , you HAVE to convert bar into atm first so the pressure would be 1.204 atm.

17. You have two balloons filled with helium gas. Balloon X is at 300 K. Balloon Y is at a different temperature. If the rate of effusion in Balloon Y is twice that as in Balloon X, what is the temperature of Balloon Y?

- a. 600 K
- b. 300 K
- c. 150 K
- d. 1200 K
- e. 75 K

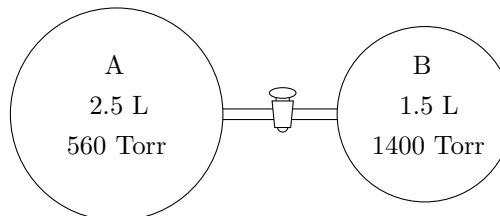
**Explanation:** If the rate is  $2\times$  higher for higher T, then the temperature will be  $2^2$  or  $4\times$  the temperature.  $4(300) = 1200$  K.

18. A gold coin weighs 1.00 Troy ounces. If 1 Troy ounce is equal to 31.104 grams, how many atoms of gold are in the gold coin?

- a.  $1.87 \times 10^{25}$  Au atoms
- b.  $9.32 \times 10^{25}$  Au atoms
- c.  $1.94 \times 10^{22}$  Au atoms
- d.  $9.51 \times 10^{22}$  Au atoms

**Explanation:**  $31.104 \text{ g Au} / 196.97 \text{ g/mol} = 0.1579$  mol  $\times 6.022 \times 10^{23} = 9.51 \times 10^{22}$  atoms of Au.

19. (Part 1 of 2) There are two glass bulbs of gases A and B connected by a closed valve as depicted in the diagram along with the volumes and pressures in each bulb.



The valve is now opened and the gases completely mix. What is partial pressure of gas A in this mixture?

- a. 350 Torr
- b. 480 Torr
- c. 280 Torr
- d. 420 Torr
- e. 300 Torr

**Explanation:** Use Boyle's Law to get new pressures for each gas. Final volume is  $2.5 + 1.5 = 4.0$  L. Therefore, after opening the valve,  $560(2.5/4) = 350$  Torr A.  $1400(1.5/4) = 525$  Torr B.

20. (Part 2 of 2) What is the mole fraction of Gas A after the valve is opened?

- a. 0.500
- b. 0.400
- c. 0.286
- d. 0.375
- e. 0.425

**Explanation:** Use pressures in previous problem to get mole fraction via  $X_A = P_A/P_{\text{total}}$ . The numbers are  $350/(350+525) = 0.400$  mole fraction A.

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After you are finished and have all your answers circled, go to the front of the room and then use the QR code there to pull up the virtual answer page. Enter the appropriate info plus all your answers - click the SUBMIT button. Make sure you get the confirmation screen and show it to the TA or proctor. After that, turn in your exam and scratch paper. You're free to leave after that.



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