

CHAPTER 4 QUESTIONS

Multiple-Choice Questions

1. Why does CaF_2 have a higher melting point than NH_3 ?
 - (A) CaF_2 is more massive and thus has stronger London dispersion forces.
 - (B) CaF_2 exhibits network covalent bonding, which is the strongest type of bonding.
 - (C) CaF_2 is smaller and exhibits greater Coulombic attractive forces.
 - (D) CaF_2 is an ionic substance and it requires a lot of energy to break up an ionic lattice.
2. Which of the following pairs of elements is most likely to create an interstitial alloy?
 - (A) Titanium and copper
 - (B) Aluminum and lead
 - (C) Silver and tin
 - (D) Magnesium and calcium
3. Why can a molecule with the structure of NBr_5 not exist?
 - (A) Nitrogen only has two energy levels and is thus unable to expand its octet.
 - (B) Bromine is much larger than nitrogen and cannot be a terminal atom in this molecule.
 - (C) It is impossible to complete the octets for all six atoms using only valence electrons.
 - (D) Nitrogen does not have a low enough electronegativity to be the central atom of this molecule.

Use the following information to answer questions 4-7.

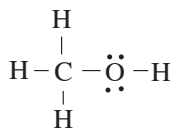
An evacuated rigid container is filled with exactly 2.00 g of hydrogen and 10.00 g of neon. The temperature of the gases is held at 0°C and the pressure inside the container is a constant 1.0 atm.

4. What is the mole fraction of neon in the container?
 - (A) 0.17
 - (B) 0.33
 - (C) 0.67
 - (D) 0.83
5. What is the volume of the container?
 - (A) 11.2 L
 - (B) 22.4 L
 - (C) 33.5 L
 - (D) 48.8 L
6. A sample of liquid NH_3 is brought to its boiling point. Which of the following occurs during the boiling process?
 - (A) The N–H bonds within the NH_3 molecules break apart.
 - (B) The overall temperature of the solution rises as the NH_3 molecules speed up.
 - (C) The amount of energy within the system remains constant.
 - (D) The hydrogen bonds holding separate NH_3 molecules together break apart.

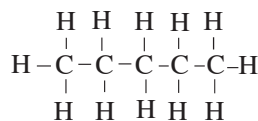
7. Which gas particles have a higher RMS velocity and why?
- (A) Hydrogen, because it has a lower molar mass
 - (B) Neon, because it has a higher molar mass
 - (C) Hydrogen, because it has a larger atomic radius
 - (D) Neon, because it has a smaller atomic radius
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8. Which of the following compounds would have the highest lattice energy?
- (A) LiF
 - (B) MgCl₂
 - (C) CaBr₂
 - (D) C₂H₆

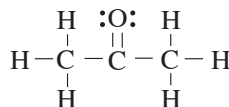
9. The following diagrams show the Lewis structures of four different molecules. Which molecule would travel the farthest in a paper chromatography experiment using a polar solvent?



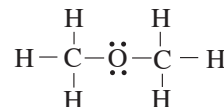
Methanol



Pentane



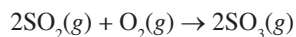
Acetone



Ether

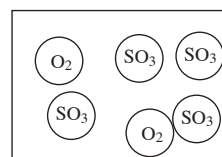
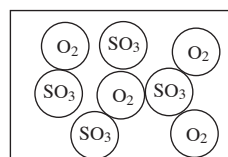
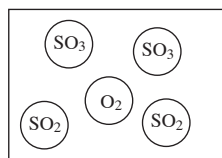
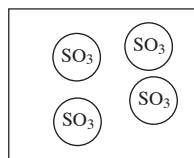
- (A) Methanol
 - (B) Pentane
 - (C) Acetone
 - (D) Ether
10. The six carbon atoms in a benzene molecule are shown in different resonance forms as three single bonds and three double bonds. If the length of a single carbon–carbon bond is 154 pm and the length of a double carbon–carbon bond is 133 pm, what length would be expected for the carbon–carbon bonds in benzene?
- (A) 126 pm
 - (B) 133 pm
 - (C) 140 pm
 - (D) 154 pm

Use the following information to answer questions 11-14.



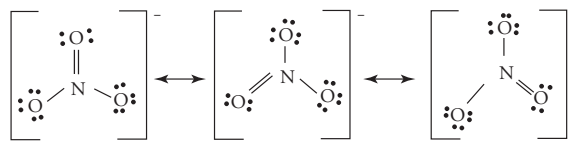
4.0 mol of gaseous SO_2 and 6.0 mol of O_2 gas are allowed to react in a sealed container.

11. Which particulate drawing best represents the contents of the flask after the reaction goes to completion?

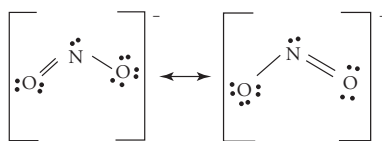


12. If the temperature remains constant, what percentage of the original pressure will the final pressure in the container be equal to?
- (A) 67%
(B) 80%
(C) 100%
(D) 133%
13. At a given point in the reaction, all three gases are present at the same temperature. Which gas molecules will have the highest velocity and why?
- (A) The O_2 molecules, because they have the least mass
(B) The O_2 molecules, because they are the smallest
(C) The SO_3 molecules, because they are products in the reaction
(D) Molecules of all three gases will have the same speed because they have the same temperature.
14. Under which of the following conditions would the gases in the container most deviate from ideal conditions and why?
- (A) Low pressures, because the gas molecules would be spread far apart
(B) High pressures, because the gas molecules will be colliding frequently
(C) Low temperatures, because the intermolecular forces between the gas molecules would increase
(D) High temperatures, because the gas molecules are moving too fast to interact with each other

15. A mixture of helium and neon gases has a total pressure of 1.2 atm. If the mixture contains twice as many moles of helium as neon, what is the partial pressure due to neon?
- (A) 0.2 atm
 (B) 0.3 atm
 (C) 0.4 atm
 (D) 0.8 atm
16. Nitrogen gas was collected over water at 25°C. If the vapor pressure of water at 25°C is 23 mmHg, and the total pressure in the container is measured at 781 mmHg, what is the partial pressure of the nitrogen gas?
- (A) 46 mmHg
 (B) 551 mmHg
 (C) 735 mmHg
 (D) 758 mmHg
17. A 22.0 gram sample of an unknown gas occupies 11.2 liters at standard temperature and pressure. Which of the following could be the identity of the gas?
- (A) CO₂
 (B) SO₃
 (C) O₂
 (D) He
18. Lewis diagrams for the nitrate and nitrite ions are shown below. Choose the statement that correctly describes the relationship between the two ions in terms of bond length and bond energy.

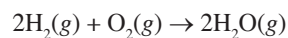


Nitrate



Nitrite

- (A) Nitrite has longer and stronger bonds than nitrate.
 (B) Nitrite has longer and weaker bonds than nitrate.
 (C) Nitrite has shorter and stronger bonds than nitrate.
 (D) Nitrite has shorter and weaker bonds than nitrate.
19. In an experiment 2 moles of H₂(g) and 1 mole of O₂(g) were completely reacted, according to the following equation in a sealed container of constant volume and temperature:



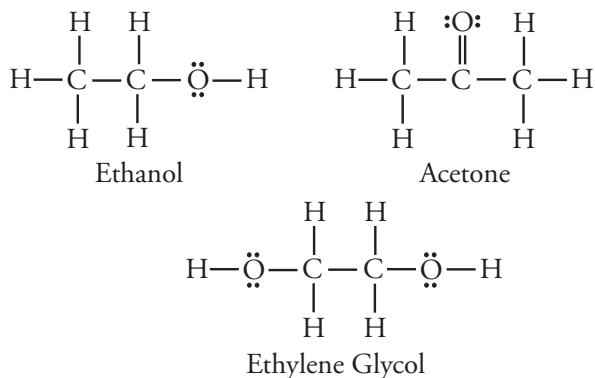
If the initial pressure in the container before the reaction is denoted as P_i , which of the following expressions gives the final pressure, assuming ideal gas behavior?

- (A) P_i
 (B) $2P_i$
 (C) $(3/2)P_i$
 (D) $(2/3)P_i$

20. A gas sample with a mass of 10 grams occupies 5.0 liters and exerts a pressure of 2.0 atm at a temperature of 26°C. Which of the following expressions is equal to the molecular mass of the gas? The gas constant, R , is 0.08 (L·atm)/(mol·K).
- (A) $(0.08)(299)$ g/mol
 (B) $\frac{(299)(0.50)}{(2.0)(0.08)}$ g/mol
 (C) $\frac{299}{0.08}$ g/mol
 (D) $(2.0)(0.08)$ g/mol
21. How many moles of Na_2SO_4 must be added to 500 milliliters of water to create a solution that has a 2-molar concentration of the Na^+ ion? (Assume the volume of the solution does not change).
- (A) 0.5 mol
 (B) 1 mol
 (C) 2 mol
 (D) 5 mol

Use the following Lewis diagrams to answer questions 22-24.

The following three substances are kept in identical containers 25°C. All three substances are in the liquid phase:

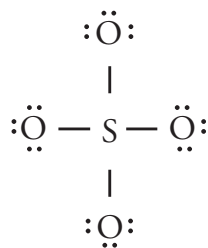


22. Which substance would have the highest boiling point?
- (A) Ethanol, because it is the most asymmetrical
 (B) Acetone, because of the double bond
 (C) Ethylene glycol, because it has the most hydrogen bonding
 (D) All three substances would have very similar boiling points because their molar masses are similar.
23. Which substance would have the highest vapor pressure?
- (A) Ethanol, because of the hybridization of its carbon atoms
 (B) Acetone, because it exhibits the weakest intermolecular forces
 (C) Ethylene glycol, because it has the most lone pairs assigned to individual atoms
 (D) All three substances would have similar vapor pressure because they have a similar number of electrons.

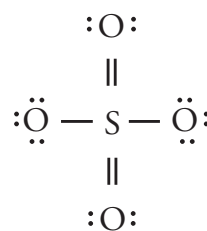
24. Which of the substances would be soluble in water?
- (A) Ethylene glycol only, because it has the longest bond lengths
 - (B) Acetone only, because it is the most symmetrical
 - (C) Ethanol and ethylene glycol only, because of their hydroxyl (–OH) groups
 - (D) All three substances would be soluble in water due to their permanent dipoles.
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Use the following information to answer questions 25-28.

There are several different potential different Lewis diagrams for the sulfate ion, two of which are below.



Structure A

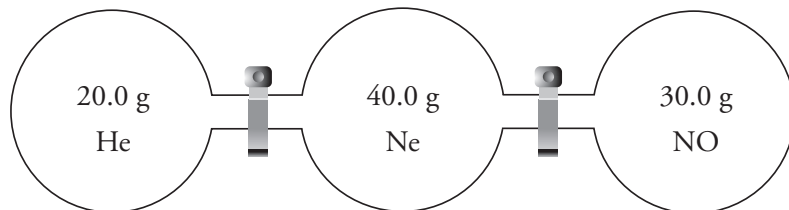


Structure B

25. What is the molecular geometry in the structure A?
- (A) Tetrahedral
 - (B) Trigonal Planar
 - (C) Trigonal Pyramidal
 - (D) Octahedral
26. What is the S–O bond order in the structure B?
- (A) 1.0
 - (B) 1.33
 - (C) 1.5
 - (D) 1.67
27. Which of the following statements regarding the structure B is true?
- (A) The double bonds must be located opposite of each other due to additional electron repulsion.
 - (B) It is a more polar molecule than the molecule represented by structure A.
 - (C) The bonds in the molecule are weaker than those in structure A.
 - (D) All bonds in the molecule are identical to each other.
28. Which structure is more likely to correspond with the actual Lewis diagram for the sulfate ion?
- (A) Structure A; single bonds are more stable than double bonds
 - (B) Structure A; it has the most unshared pairs of electrons
 - (C) Structure B; there are more possible resonance structures
 - (D) Structure B; fewer atoms have formal charges
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Use the following information to answer questions 29-31.

The diagram below shows three identical 1.0 L containers filled with the indicated amounts of gas. The stopcocks connecting the containers are originally closed and the gases are all at 25°C. Assume ideal behavior.



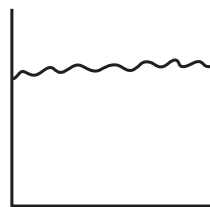
29. Which gas exerts the greatest pressure?
- (A) He
 - (B) Ne
 - (C) NO
 - (D) All gases exert the same amount of pressure.
30. Which gas has the strongest IMFs?
- (A) He
 - (B) Ne
 - (C) NO
 - (D) All gases have identical IMFs.
31. The stopcocks are opened. If the tubing connecting the containers has negligible volume, by what percentage will the pressure exerted by the neon gas decrease?
- (A) 25%
 - (B) 33%
 - (C) 50%
 - (D) 67%
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Free-Response Questions

1. A 250 mL Erlenmeyer flask contains a mixture of two liquids: diethyl ether and ethylamine. The flask is attached to a distillation apparatus and heated until the mixture starts to boil.
 - (a) Why is it important to keep the flask at a constant temperature once the mixture starts to boil?
 - (b)
 - (i) Which liquid is the primary component of the distillate? Justify your answer in terms of IMFs.
 - (ii) The distillate is not a completely pure substance. Why?
 - (c) After the distillate is collected, half of it is transferred into a 250 mL beaker, as shown below. If both containers are left uncovered, which liquid (if either) will evaporate first? Why?



250 ml flask



250 ml beaker

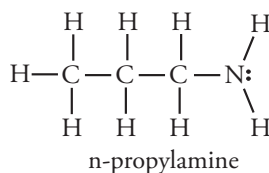
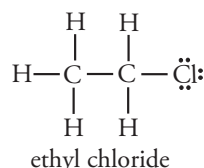
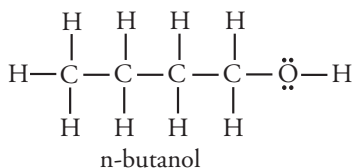
2. The carbonate ion CO_3^{2-} is formed when carbon dioxide, CO_2 , reacts with slightly basic cold water.
 - (a)
 - (i) Draw the Lewis electron dot structure for the carbonate ion. Include resonance forms if they apply.
 - (ii) Draw the Lewis electron dot structure for carbon dioxide.
 - (b) Describe the hybridization of carbon in the carbonate ion.
 - (c)
 - (i) Describe the relative lengths of the three C–O bonds in the carbonate ion.
 - (ii) Compare the average length of the C–O bonds in the carbonate ion to the average length of the C–O bonds in carbon dioxide.

3.

Substance	Boiling Point (°C)	Bond Length (Å)	Bond Strength (kcal/mol)
H ₂	-253°	0.75	104.2
N ₂	-196°	1.10	226.8
O ₂	-182°	1.21	118.9
Cl ₂	-34°	1.99	58.0

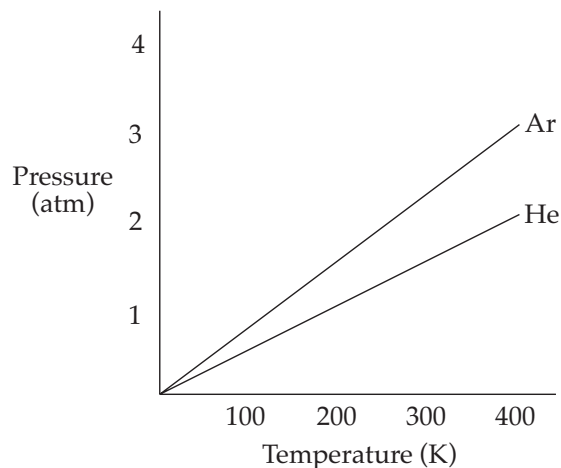
- (a) Explain the differences in the properties given in the table above for each of the following pairs.
- The bond strengths of N₂ and O₂
 - The bond lengths of H₂ and Cl₂
 - The boiling points of O₂ and Cl₂
- (b) Use the principles of molecular bonding to explain why H₂ and O₂ are gases at room temperature, while H₂O is a liquid at room temperature.

4. A student has a mixture containing three different organic substances. The Lewis diagrams of the substances are below:



- (a) If the mixture was dabbed onto chromatography paper that was then placed into a nonpolar solvent, rank the R_f values for each component of the mixture from high to low after the solvent has saturated the paper. Justify your answer.
- (b) If the mixture is poured into a chromatography column and then eluted with a very polar substance, which component of the mixture would leave the column first, and why?
- (c) (i) The mixture is heated until it begins to boil. Which substance would be the easiest to separate via distillation, and why?
 (ii) After the substance begins boiling, it continues to be heated at the same rate. Compared to the rate at which it was changing prior to boiling, will the temperature increase faster, slower, or at the same rate? Explain.
- (d) (i) After the components of the mixture have been separated, they are returned to room temperature. Of the three substances, which would have the highest vapor pressure at room temperature? Justify your answer.
 (ii) If the substances were heated (but not boiled), explain what would happen to their vapor pressures.

5.



The graph above shows the changes in pressure with changing temperature of gas samples of helium and argon confined in a closed 2-liter vessel.

- What is the total pressure of the two gases in the container at a temperature of 200 K?
- How many moles of helium are contained in the vessel?
- How many molecules of helium are contained in the vessel?
- Molecules of which gas will have a greater distribution of velocities at 200 K? Justify your answer.
- If the volume of the container were reduced to 1 liter at a constant temperature of 300 K, what would be the new pressure of the helium gas?

6.



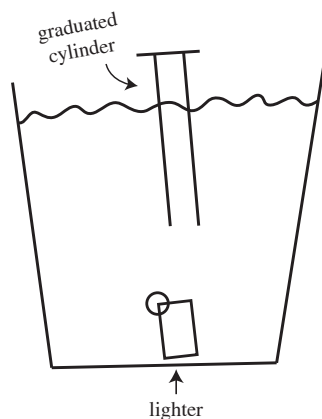
The reaction above took place, and 1.45 liters of oxygen gas were collected over water at a temperature of 29°C and a pressure of 755 millimeters of mercury. The vapor pressure of water at 29°C is 30.0 millimeters of mercury.

- What is the partial pressure of the oxygen gas collected?
- How many moles of oxygen gas were collected?
- What would be the dry volume of the oxygen gas at a pressure of 760 millimeters of mercury and a temperature of 273 K?
- What was the mass of the KClO_3 consumed in the reaction?

7. Equal molar quantities of two gases, O_2 and H_2O , are confined in a closed vessel at constant temperature.

- Which gas, if either, has the greater partial pressure?
- Which gas, if either, has the greater density?
- Which gas, if either, has the greater concentration?
- Which gas, if either, has the greater average kinetic energy?
- Which gas, if either, will show the greater deviation from ideal behavior?

8. A student performs an experiment in which a butane lighter is held underwater directly beneath a 100-mL graduated cylinder which has been filled with water as shown in the diagram below.



The switch on the lighter is pressed, and butane gas is released into the graduated cylinder. The student's data table for this lab is as follows:

Mass of lighter before gas release	20.432 g
Mass of lighter after gas release	20.296 g
Volume of gas collected	68.40 mL
Water Temperature	19.0°C
Atmospheric Pressure	745 mmHg

- (a) Given that the vapor pressure of water at 19.0°C is 16.5 mmHg, determine the partial pressure of the butane gas collected in atmospheres.
- (b) Calculate the molar mass of butane gas from the experimental data given.
- (c) If the formula of butane is C_4H_{10} , determine the percent error for the student's results.
- (d) The following are common potential error sources that occur during this lab. Explain whether or not each error could have been responsible for the error in the student's results.
- The lighter was not sufficiently dried before massing it after the gas was released.
 - The gas in the lighter was not held underwater long enough to sufficiently cool it to the same temperature of the water and was actually at a higher temperature than the water.
 - Not all of the butane gas released was collected in the graduated cylinder.