CHAPTER 4 QUESTIONS

Multiple-Choice Questions

1. A sealed, rigid container contains three gases: 28.0 g of nitrogen, 40.0 g of argon, and 36.0 g of water vapor. If the total pressure exerted by the gases is 2.0 atm, what is the partial pressure of the nitrogen?

   (A) 0.33 atm
   (B) 0.40 atm
   (C) 0.50 atm
   (D) 2.0 atm

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 4-6.**

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. 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

7. 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.

8. Which of the following compounds would have the highest lattice energy?

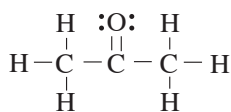   (A) LiF
   (B) $MgCl_2$
   (C) $CaBr_2$
   (D) C_2H_6

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?
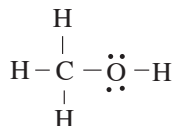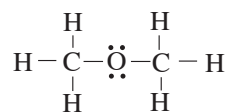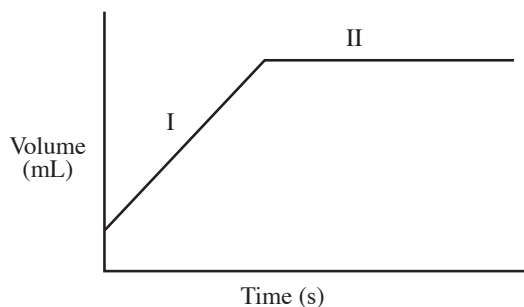
Methanol
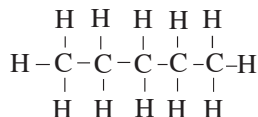
Pentane

Acetone

Ether

   (A) Methanol
   (B) Pentane
   (C) Acetone
   (D) Ether

10.

The volume of a gas is charted over time, giving the above results. Which of the following options provides a possible explanation of what was happening to the gas during each phase of the graph?

   (A) During phase I, the temperature decreased while the pressure increased. During phase II, the temperature was held constant as the pressure decreased.
   (B) During phase I, the temperature increased while the pressure was held constant. During phase II, the temperature and pressure both decreased.
   (C) During phase I, the temperature was held constant while the pressure increased. During phase II, the temperature and pressure both decreased.
   (D) During phase I, the temperature and pressure both increased. During phase II, the temperature was held constant while the pressure decreased.

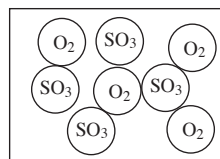**Use the following information to answer questions 11-13.**

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$
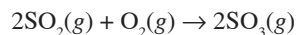
4.0 mol of gaseous SO_2 and 6.0 mol of O_2 gas are allowed to react in a sealed container.
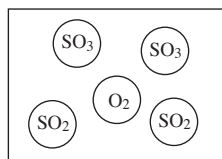
11. Which particulate drawing best represents the contents of the flask after the reaction goes to completion?
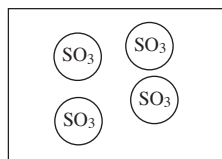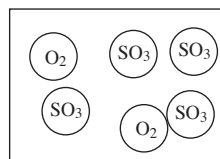

(A)

(C)

(B)

(D)

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. 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 one another

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14. $$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$
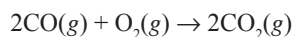
2.0 mol of $CO(g)$ and 2.0 mol of $O_2(g)$ are pumped into a rigid, evacuated 4.0-L container, where they react to form $CO_2(g)$. Which of the following values does NOT represent a potential set of concentrations for each gas at a given point during the reaction?

	CO	O_2	CO_2
(A)	0.5	0.5	0
(B)	0	0.25	0.5
(C)	0.25	0.25	0.5
(D)	0.25	0.38	0.25

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) CO_2
    (B) SO_3
    (C) O_2
    (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.
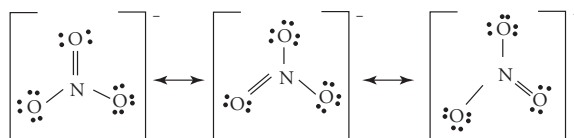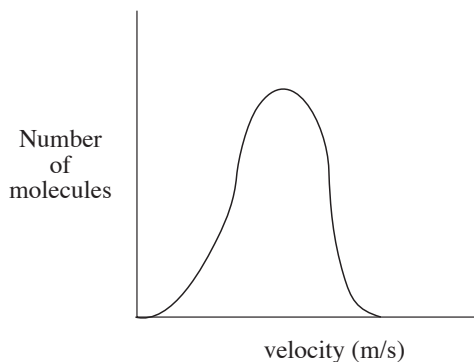

Nitrate
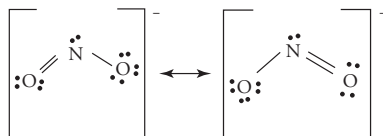

Nitrite

    (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.
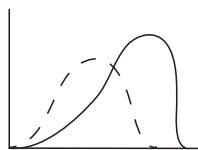   (D) Nitrite has shorter and weaker bonds than nitrate.

19.

velocity (m/s)

The diagram above shows the speed distribution of molecules in a gas held at 200 K. Which of the following representations would best represent the gas at a higher temperature? (Note: The original line is shown as a dashed line in the answer options.)
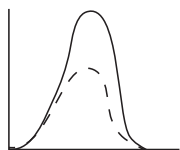
(A)

(C)
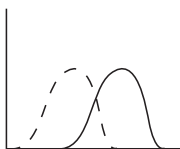
(B)
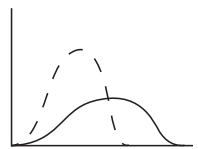
(D)

20. A sample of oxygen gas at 50°C is heated, reaching a final temperature of 100°C. Which statement best describes the behavior of the gas molecules?

(A) Their velocity increases by a factor of two.
(B) Their velocity increases by a factor of four.
(C) Their kinetic energy increases by a factor of 2.
(D) Their kinetic energy increases by a factor of less than 2.

Use the following information to answer questions 21-23.

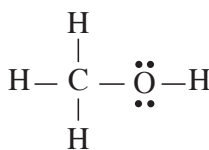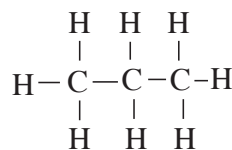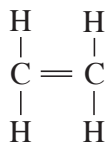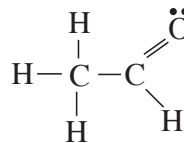$$H - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} - \overset{\cdot\cdot}{\underset{\cdot\cdot}{O}} - H$$

Methanol

$$H - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} - H$$

Propane

$$\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} = \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}$$

Ethene

$$H - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} - C \overset{\displaystyle \overset{\cdot\cdot}{O}}{\underset{\displaystyle H}{\diagdown}}$$

Ethanal

21. Based on the strength of the intermolecular forces in each substance, estimate from greatest to smallest the vapor pressures of each substance in liquid state at the same temperature.

    (A) Propane > Ethanal > Ethene > Methanol
    (B) Ethene > Propane > Ethanal > Methanol
    (C) Ethanal > Methanol > Ethene > Propane
    (D) Methanol > Ethanal > Propane > Ethene

22. When in liquid state, which two substances are most likely to be miscible with water?

    (A) Propane and ethene
    (B) Methanol and propane
    (C) Ethene and ethanal
    (D) Methanol and ethanal

23. Between propane and ethene, which will likely have the higher boiling point and why?

    (A) Propane, because it has a greater molar mass
    (B) Propane, because it has a more polarizable electron cloud
    (C) Ethene, because of the double bond
   (D) Ethene, because it is smaller in size

24. The graph below shows the amount of potential energy between two hydrogen atoms as the distance between them changes. At which point in the graph would a molecule of H_2 be the most stable?
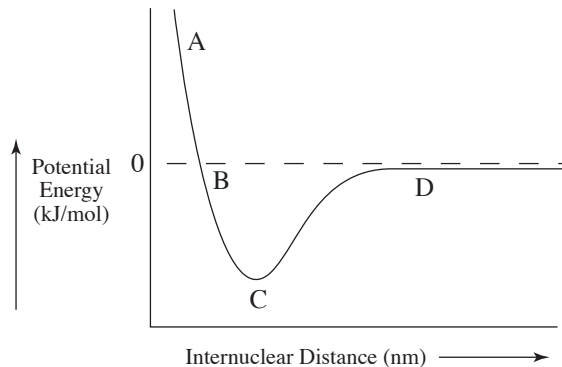
(A) Point A
(B) Point B
(C) Point C
(D) Point D

Use the following information to answer questions 25-28.

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

Structure A   Structure B
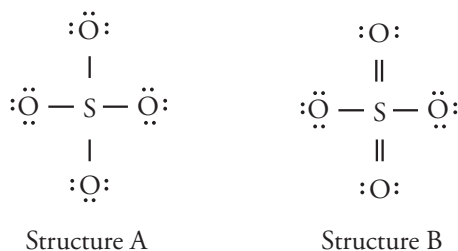
25. What is the molecular geometry in the structure A?

(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

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.
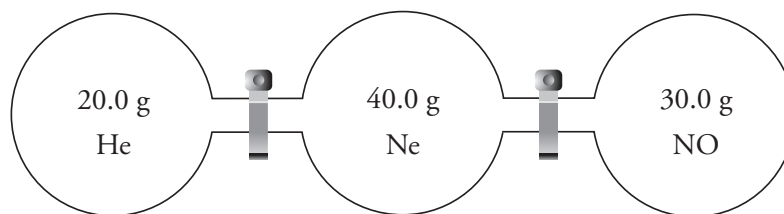
29. Which gas exerts the greatest pressure?

   (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%


32. A sample of an unknown chloride compound was dissolved in water, and then titrated with excess $Pb(NO_3)_2$ to create a precipitate. After drying, it is determined there are 0.0050 mol of precipitate present. What mass of chloride is present in the original sample?

    (A)   0.177 g
    (B)   0.355 g
    (C)   0.522 g
    (D)   0.710 g

Free-Response Questions
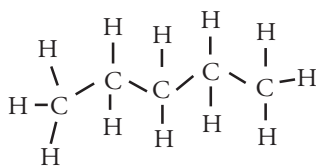
1. Consider the Lewis structures for the following four molecules:
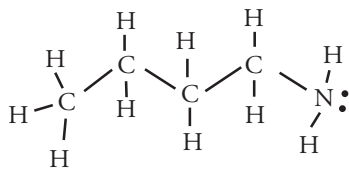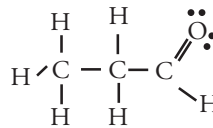
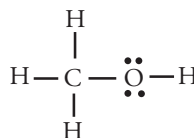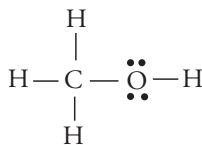n-Butylamine   Propanal

Pentane   Methanol

(a)   All of the substances are liquids at room temperature. Organize them from high to low in terms of boiling points, clearly differentiating between the intermolecular forces in each substance.

(b)   On the methanol diagram reproduced below, draw the locations of all dipoles.

Methanol

(c)   n-Butylamine is found to have the lowest vapor pressure at room temperature out of the four liquids. Justify this observation in terms of intermolecular forces.

2. The acetyl ion has a formula of $C_2H_3O^-$ and two possible Lewis electron-dot diagram representations:
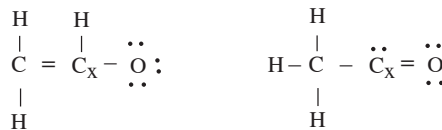
(a)   Using formal charge, determine which structure is the most likely correct structure.
(b)   For carbon atom "x" in the structure you chose:
    (i)   What is the hybridization around the atom?
    (ii) How many sigma and pi bonds has the atom formed?
(c)   A hydrogen ion attaches itself to the acetyl ion, creating C_2H_4O. Draw the Lewis diagram of the new molecule.

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.
  (i) The bond strengths of N_2 and O_2
  (ii) The bond lengths of H_2 and Cl_2
  (iii) The boiling points of O_2 and Cl_2
(b) Use the principles of molecular bonding to explain why H_2 and O_2 are gases at room temperature, while H_2O 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:

n-butanol

ethyl chloride

n-propylamine
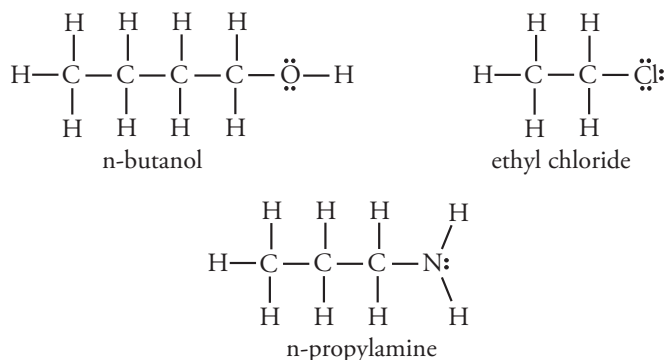
(a) If the mixture was dabbed onto chromatography paper that was then placed into a nonpolar solvent, rank the R_f values for each component of the mixture from high to low after the solvent has saturated the paper. Justify your answer.
(b) If the mixture is poured into a chromatography column and then 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.
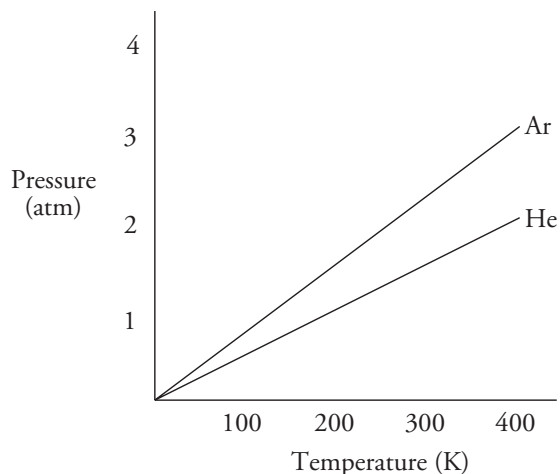
The graph above shows the changes in pressure with changing temperature of gas samples of helium and argon confined in a closed 2-liter vessel.

(a)   What is the total pressure of the two gases in the container at a temperature of 200 K?

(b)   How many moles of helium are contained in the vessel?

(c)   How many molecules of helium are contained in the vessel?

(d)   Molecules of which gas will have a greater distribution of velocities at 200 K? Justify your answer.

(e)   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. $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$

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.

(a)   What is the partial pressure of the oxygen gas collected?

(b)   How many moles of oxygen gas were collected?

(c)   What would be the dry volume of the oxygen gas at a pressure of 760 millimeters of mercury and a temperature of 273 K?

(d)   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.

   (a) Which gas, if either, has the greater partial pressure?
   (b) Which gas, if either, has the greater density?
   (c) Which gas, if either, has the greater concentration?
   (d) Which gas, if either, has the greater average kinetic energy?
   (e) 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.
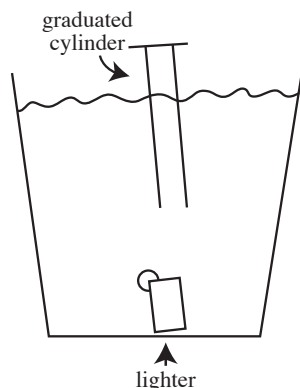
The switch on the lighter is pressed, and butane gas is released into the graduated cylinder. The student's data table for this lab is as follows:

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.
       (i) The lighter was not sufficiently dried before massing it after the gas was released.
       (ii) 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.
       (iii) Not all of the butane gas released was collected in the graduated cylinder.