TOPIC C PROBLEMS

REVIEW of the fundamentals of working with the ideal gas law and the combined gas law.

R-1) A container holds 415 mL of air at a pressure of 1.88 atm. If you want to reduce the pressure to 1.55 atm without changing the temperature, to what volume must you expand the air?

R-2) A balloon is filled with 3.85 L of oxygen at 31ºC and a pressure of 734 torr. The balloon is then taken to the top of a mountain, where the pressure is 591 torr. The volume of the oxygen is found to be 4.13 L. What is the temperature of the oxygen? Give your answer in ºC.

R-3) A container is filled with gaseous O_2 at 21.4˚C (70.5˚F) and a pressure of 754 torr. If the volume of the container is one gallon (3785 mL), what is the mass of the O_2?

R-4) A container is filled with 25.3 g of gaseous CO_2 at 31ºC. If the carbon dioxide exerts a pressure of 3.88 atm, what is the volume of the container?

R-5) What is the density of gaseous carbon dioxide at 51ºC and a pressure of 855 torr?

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1) A gaseous compound has the following composition: 85.63% carbon, 14.37% hydrogen. The density of this compound is 1.63 g/L at 33.2ºC and a pressure of 739 torr. What is the molecular formula of the compound?

2) Copper reacts with nitric acid as shown below:

$$Cu(s) + 4\ HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2\ NO_2(g) + 2\ H_2O(l)$$

If 4.71 g of copper reacts with excess 3 M nitric acid, what volume of nitrogen dioxide will be formed at 31ºC and 1.022 atm?

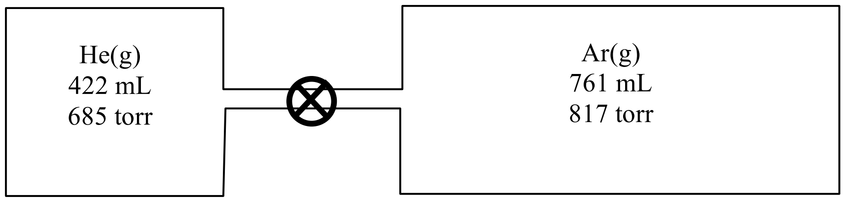
3) Consider the following reaction:

$$4\ Cr^{2+}(aq) + O_2(g) + 4\ H^+(aq) \rightarrow 4\ Cr^{3+}(aq) + 2\ H_2O(l)$$

A container that holds 562 mL of gaseous oxygen at 21ºC is prepared. Then, 21.3 mL of a solution that contains 0.131 M Cr^{2+} ions is added to the container. After the reaction, the pressure of the oxygen in the container is found to be 119 torr and the temperature is still 21ºC. What was the pressure of oxygen in the container before the Cr^{2+} solution was added? (You can assume that H^+ is present in excess.)

4) A chemist puts 200.0 mL of water into a 2.50 L container, and adds enough gaseous H_2S to give a pressure of 180.2 torr at a temperature of 13.0˚C. Some of the H_2S then dissolves in the water, causing the pressure in the container to drop to 155.9 torr. The temperature remains constant throughout this experiment. What is the molar concentration of H_2S in the water at the end of the experiment?

5) Consider the apparatus pictured below, which consists of two containers separated by a valve.



Assuming that the two gases are the same temperature and that the temperature does not change, what will be the total final pressure in the system after the valve is opened and the gases mix completely?

6) Complete the following ICE table. All of the reactants and products for this reaction are gases, and the temperature and volume are constant during the reaction.

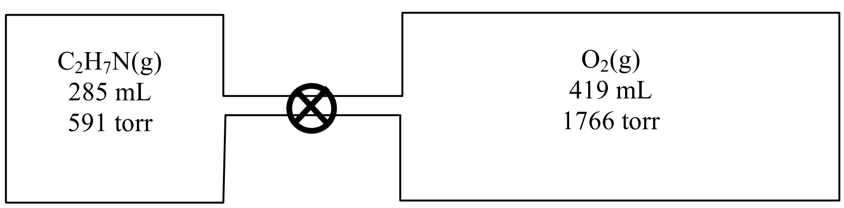
	C_2H_6	+	$7\ F_2$	$\rightarrow$	$2\ CF_4$	+	$6\ HF$
Initial pressure (torr):	127.3		329.5		89.1		0
Change (torr):							
Ending pressure (torr):							

7) At 30ºC, propylene (C_3H_6) reacts with chlorine as follows:

$$C_3H_6(g) + 9\ Cl_2(g) \rightarrow 3\ CCl_4(l) + 6\ HCl(g)$$

A mixture containing 15.5 torr of C_3H_6 and 174.5 torr of Cl_2 is allowed to react at 30ºC. What will be the total gas pressure in the container when the reaction is complete? You may assume that the volume and temperature are constant.

8) Consider the apparatus pictured below, which consists of two containers separated by a valve.

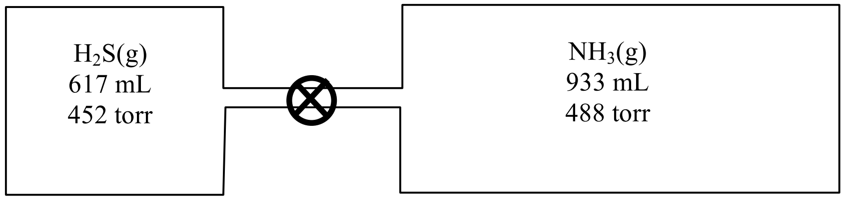


The valve is opened and the gases react as follows (note that the temperature is high enough that the water is produced as a gas):

$$4\ C_2H_7N(g) + 15\ O_2(g) \rightarrow 8\ CO_2(g) + 14\ H_2O(g) + 2\ N_2(g)$$

What will be the total pressure in the apparatus when the reaction has gone to completion? Assume that the temperature does not change.

9) Consider the apparatus pictured below, which consists of two containers separated by a valve.



The valve is opened and the gases react as follows:

$$H_2S(g) + 2\ NH_3(g) \rightarrow (NH_4)_2S(s)$$

What will be the total pressure in the apparatus when the reaction has gone to completion? Assume that the temperature does not change.

Kinetic Molecular Theory

10) This question is intended to give you a "feel" for the size of the SI energy unit.

a) Jorge weighs 69.0 kg (152 pounds). If he is walking at a speed of 1.12 m/sec (about 2.5 miles per hour), what is his kinetic energy in joules?

b) If Jorge's kinetic energy is 1.00 J, how fast is he moving?

11) The average kinetic energy of the atoms in a sample of gaseous argon at a certain temperature is 5188 J/mol.

a) What is the average kinetic energy of a single argon atom, in joules?

b) If a argon atom has the kinetic energy you calculated in part a, how fast is it moving?

c) If the argon sample weighs 1.450 g, what is the total kinetic energy of the atoms in the sample?

d) What is the temperature of the argon?

e) What is the most probable kinetic energy for the argon, in J/mol?

f) What is the root-mean-square speed of the argon atoms?

g) What is the average speed of the argon?

h) What is the most probable speed of the argon atoms?

12) A molecule of nitrogen trifluoride is moving at 426 m/sec at 25ºC.

a) What is the kinetic energy of this molecule, in joules?

b) What is the kinetic energy of this molecule, in J/mol?

c) Is this molecule moving faster than the average speed of nitrogen trifluoride molecules at this temperature?

13) A sample of O_2 is at 100ºC.

a) What temperature would a sample of O_3 (ozone) need to be in order for it to have the same average kinetic energy as the O_2?

b) What temperature would the O_3 need to be in order for it to have the same average molecular speed as the O_2?

c) What temperature would the O_3 need to be in order for it to have the same root-mean-square speed as the O_2?

14) Two identical containers are filled with gases as shown below:

Container 1: N_2O(g) at 0ºC, 700 torr

Container 2: NO_2(g) at 0ºC, 700 torr

a) Which gas has the higher rms speed? Explain how you can tell.

b) Which gas has the higher KE_{mp} (most probable kinetic energy)? Explain.

c) Which gas weighs more? Explain how you can tell.

15) Two identical containers are filled with gases as shown below:

Container 1: NO_2 at 200ºC, 1 atm   Container 2: NO at 100ºC, 1 atm

a) Which gas has the higher average kinetic energy? Explain how you can tell.

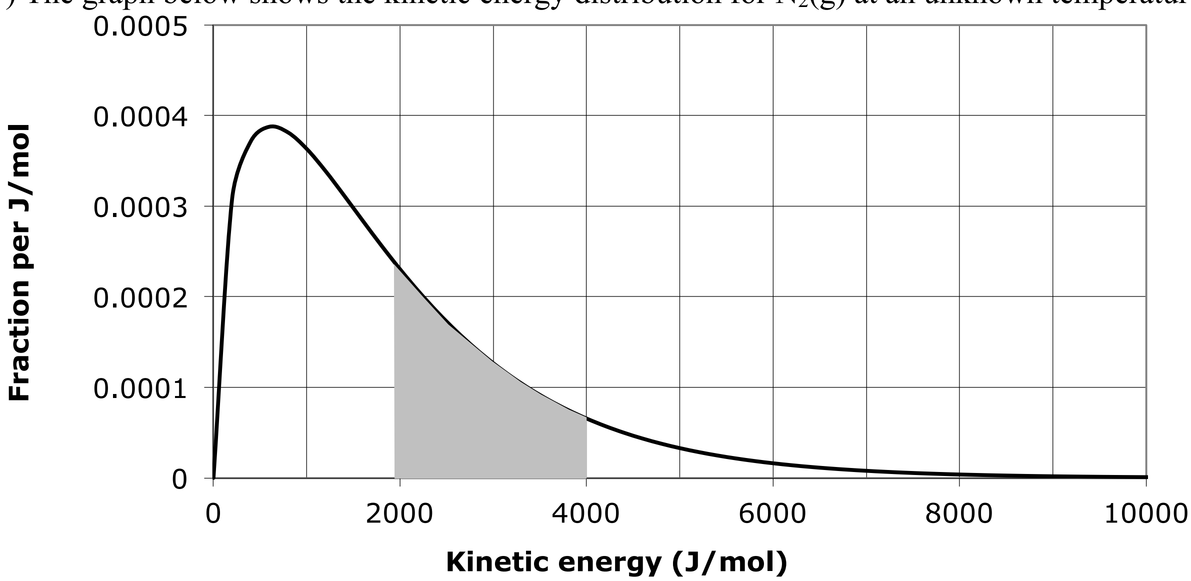
b) Which gas has the higher most probable speed? Explain how you can tell.
c) Which gas weighs more? Explain how you can tell.

16) Explain the following observations, using the kinetic theory of gases.
a) When a gas is heated, the pressure that it exerts increases.
b) Gases can easily be compressed into smaller volumes.
c) Raising the temperature of 1 mole of helium by 1ºC requires the same amount of energy as raising the temperature of 1 mole of argon by 1ºC.

17) Two identical containers are filled with gases as shown below:
Container 1: CH_4 at 0˚C, 1 atm   Container 2: C_2H_6 at 0˚C, 1 atm
a) Which gas has a larger fraction of molecules with kinetic energies greater than 5000 J/mol? Explain how you can tell.
b) Which gas has a larger fraction of molecules with speeds less than 500 m/sec? Explain how you can tell.

18) Two identical containers are filled with gases as shown below:
Container 1: Ar at 100˚C, 1 atm   Container 2: CO_2 at 125˚C, 1 atm
a) Which gas has a larger fraction of molecules with kinetic energies lower than 5000 J/mol? Explain how you can tell.
b) Which gas has a larger fraction of molecules with speeds above 500 m/sec? Explain how you can tell.

19) The graph below shows the kinetic energy distribution for $N_2(g)$ at an unknown temperature.

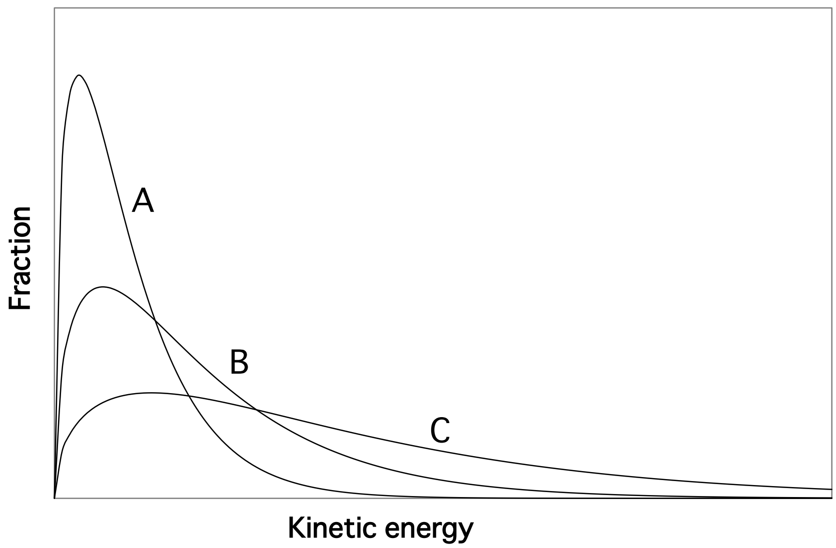


a) What is the most probable kinetic energy for the gas, based on the graph?
b) What is the approximate temperature of the gas, based on your answer to part a?
c) What is the *y* value when *x* = 2000 J/mol? What does this *y* value tell you?
d) The area of the shaded region is 0.259. What does this value tell you?

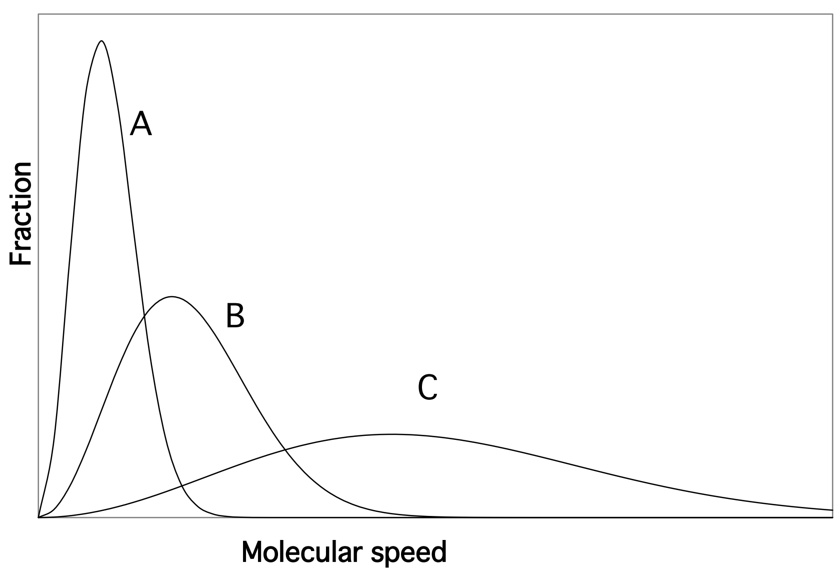
20) The following questions relate to the graph below, in which curve B represents the kinetic energy distribution for Ne(g) at 300 K.

a) Which curve (A, B, or C) could represent the kinetic energy distribution for Ar(g) at 300 K? Explain your answer briefly.

b) Which curve could represent the kinetic energy distribution for Ne(g) at 150 K? Explain your answer briefly.



21) Consider the graph below, in which curve B represents the distribution of speeds for $N_2(g)$ at 25.0ºC.



a) Which curve (A, B, or C) could represent the distribution of speeds for $N_2(g)$ at –125.0ºC? Explain your answer briefly.

b) Which curve could represent the distribution of speeds for $H_2(g)$ at 25.0ºC? Explain your answer briefly.

c) Which curve could represent the distribution of speeds for Ne(g) at –58.4ºC? Explain your answer briefly.

22) The graph below shows the distribution of speeds for an unknown gas at 200ºC.

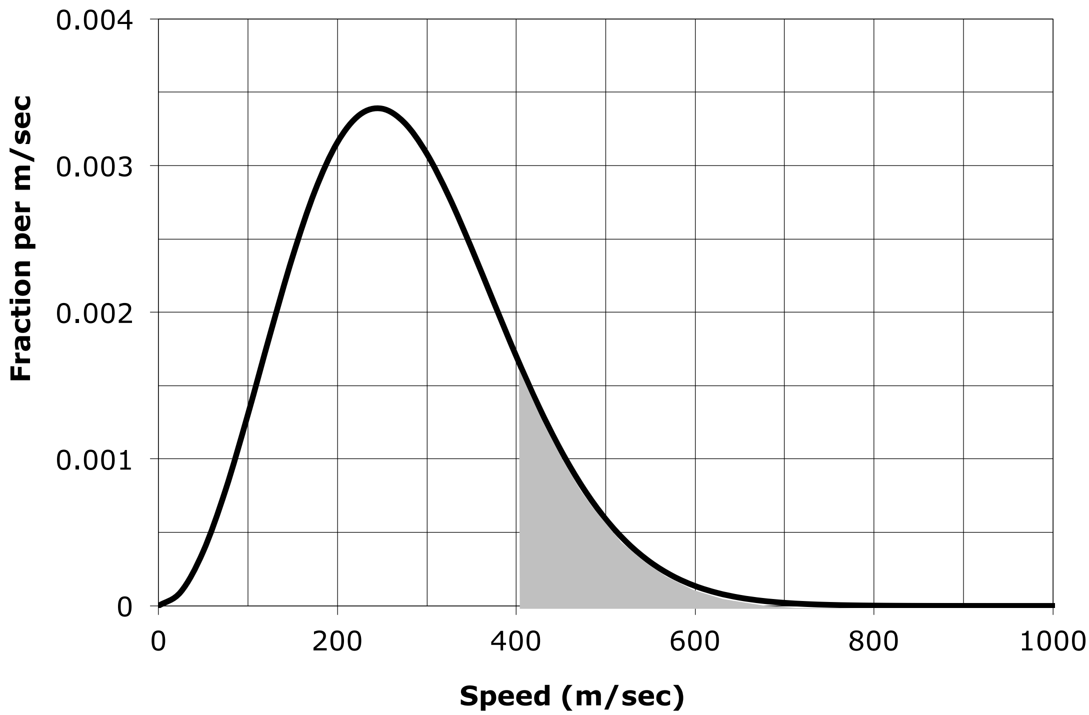
a) What is the most probable speed for this gas?

b) This gas is one of the inert gases. Which one is it, and how did you determine this?

c) What is the *y* value when *x* = 200 m/sec? What does this *y* value tell you?

d) The area of the shaded region (which extends out to infinite speed) is 0.111. What does this value tell you?

e) What is the area of the region under the curve that is not shaded? What does this value tell you?



23) At 62ºC, 5.00 mL of argon effuses through a porous barrier in 5 minutes and 13 seconds. In an identical apparatus at 62ºC, 5.00 mL of an unknown gas effuses through the barrier in 4 minutes and 22 seconds. The empirical formula of the unknown gas is CH_2. Determine the molecular formula of the gas.

24) If we compare the van der Waals constants for water and nitrogen, we see that water has a higher value of *a* while nitrogen has a higher value of *b*. The numbers are:

H_2O: $a = 5.46$ atm·L^2/mol^2 $b = 0.0305$ L/mol

N_2: $a = 1.39$ atm·L^2/mol^2 $b = 0.0391$ L/mol

a) Explain why water has the higher *a* value.

b) Explain why nitrogen has the higher *b* value.

25) An engineer is designing a reactor that will be filled with oxygen under high pressure. The volume of the reactor is 253 L, the maximum temperature inside the reactor will be 250ºC, and the pressure inside the reactor must not exceed 150 atm. The engineer uses the ideal gas law to

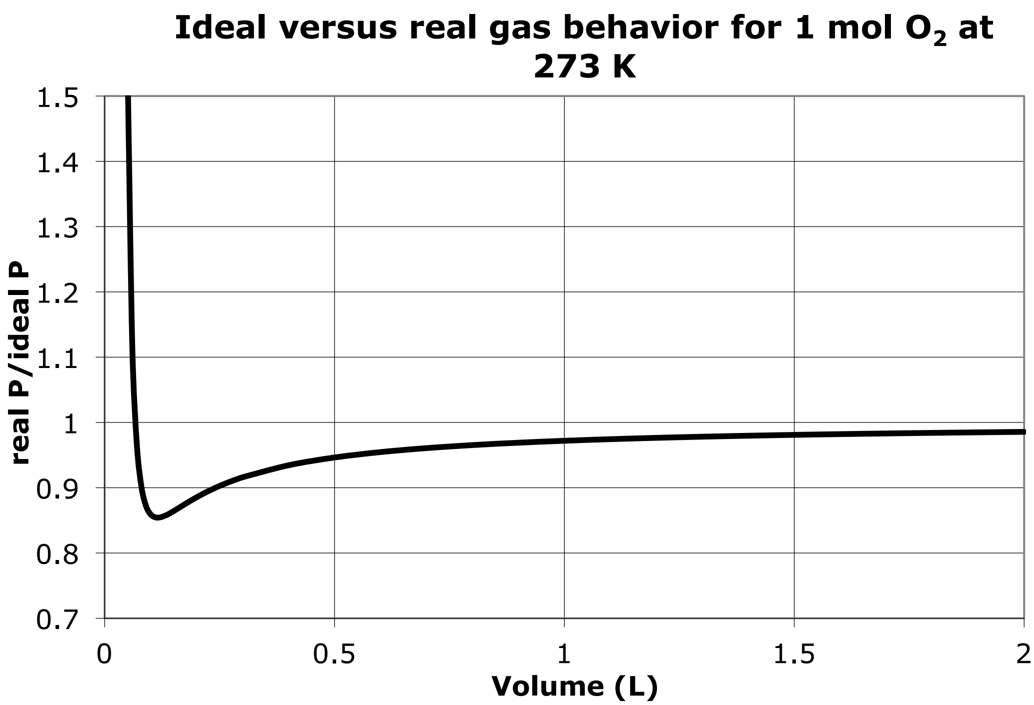
calculate the maximum number of moles of oxygen that can be put into the reactor without exceeding 150 atm.

a) What number of moles does the engineer calculate using the ideal gas law?

b) Now use the van der Waals equation to calculate a more accurate value for the pressure inside the reactor at 250ºC, using the number of moles you obtained in part a. (Van der Waals constants for oxygen are given in the textbook.)

c) Based on your answers to parts a and b, was the engineer justified in using the ideal gas law, or will she create an unsafe situation? Explain your answer briefly.

26) The graph below shows how the actual pressure of a sample of O_2 deviates from the ideal gas prediction. The values on the *y* axis are the actual pressure of the gas divided by the pressure calculated from the ideal gas law. (A *y* value of 1 means the actual pressure equals the ideal gas prediction.)



a) Based on this graph, under what conditions is the actual pressure lower than the ideal gas prediction? Why is this?

b) Based on this graph, under what conditions is the actual pressure higher than the ideal gas prediction? Why is this?