Ionic Bonding, Solids, and Gases **Name:** _____
Free Response Assessment—Coronavirus **AP Chemistry 2019-2020**

Directions

- Write your responses in the space provided following each question. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. **You must show your work to receive credit for your answer**. Pay attention to significant figures.

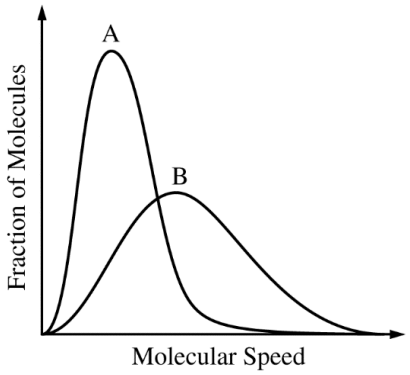
- Responses to this assessment will be submitted through Microsoft Teams. You will receive directions (written and video) about how to submit your work. You may type and/or write your answers. If you write your answers, it is NOT necessary to print this document. You may write on notebook paper and upload a PDF of your work to Teams. If you choose this option, your work should be labeled with your name, question number, and letter for each part.

Free Response Questions

1. A mixture of $H_2(g)$, $O_2(g)$, and 2 mL of $H_2O(l)$ is present in a 0.500-L rigid container at 25 °C. The number of moles of H_2 and the number of moles of O_2 are equal. The total pressure in the container is 1,146 mmHg. (The equilibrium vapor pressure of pure water is 24 mmHg at 25 °C.)

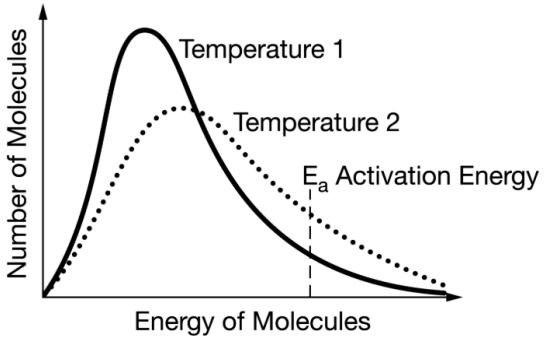
   The mixture is sparked, and H_2 and O_2 react until one reactant is completely consumed.
   The balanced equation for reaction of H_2 with O_2 is shown below.

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$



   a. The diagram above shows the distribution of molecular speeds for $H_2(g)$ and $O_2(g)$ molecules at 25°C before the reaction occurs. Match each curve (A and B) with the correct gas and justify your answer.

   b. The diagram below shows the distribution of kinetic energies for H_2 molecules at two different temperatures. Is the rate of consumption of H_2 greater at Temperature 1 or Temperature 2? Use the Maxwell-Boltzmann distribution to justify your answer in terms of reaction kinetics and the collision theory.

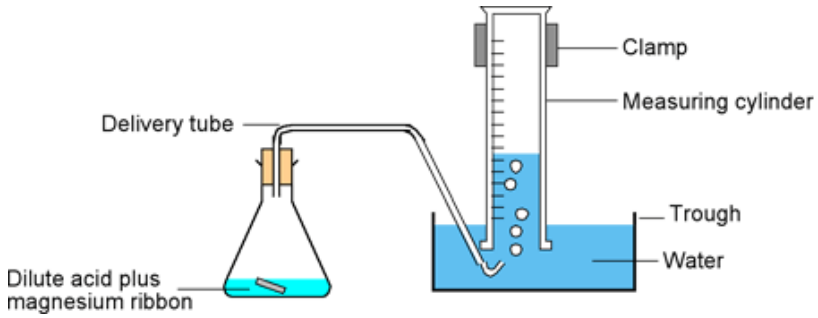


c. Use the balanced chemical equation to identify the limiting reactant. Justify your answer.
$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

d. Calculate the number of moles of excess reactant remaining in the rigid container after the reaction has gone to completion.

e. Calculate the total pressure in the container at the conclusion of the reaction if the final temperature is 90°C. The equilibrium vapor pressure of water at 90°C is 526 mmHg.

f. Calculate the number of moles of water **vapor** in the container at 90°C.



2. A student performs an experiment to determine the volume of hydrogen gas produced when a given mass of magnesium reacts with excess HCl(*aq*). The student begins with a 0.0360 g sample of pure magnesium and a solution of 2.0 *M* HCl(*aq*).
   a. Write the balanced net ionic equation for the reaction.

   b. Calculate the number of moles of magnesium in the 0.0360 g sample.

   c. Calculate the number of moles of HCl(*aq*) needed to react completely with the sample of magnesium.

   As the magnesium reacts, the hydrogen gas produced is collected by water displacement at 23.0°C. The pressure of the gas in the collection tube is measured to be 749 torr.

   d. Given that the equilibrium vapor pressure of water is 21 torr at 23.0°C, calculate the pressure that the $H_2(g)$ produced in the reaction would have if it were dry.

   e. Calculate the volume, in liters measured at the conditions in the laboratory, that the $H_2(g)$ produced in the reaction would have if it were dry.

   f. The laboratory procedure specified that the concentration of the HCl solution be 2.0 *M*, but only 12.3 *M* HCl solution was available. Describe the steps for safely preparing 50.0 mL of 2.0 *M* HCl(*aq*) using 12.3 *M* HCl solution and materials selected from the list below. Show any necessary calculations.

10.0 mL graduate cylinder	Distilled water
250 mL beakers	Balance
50.00 mL volumetric flask	Dropper

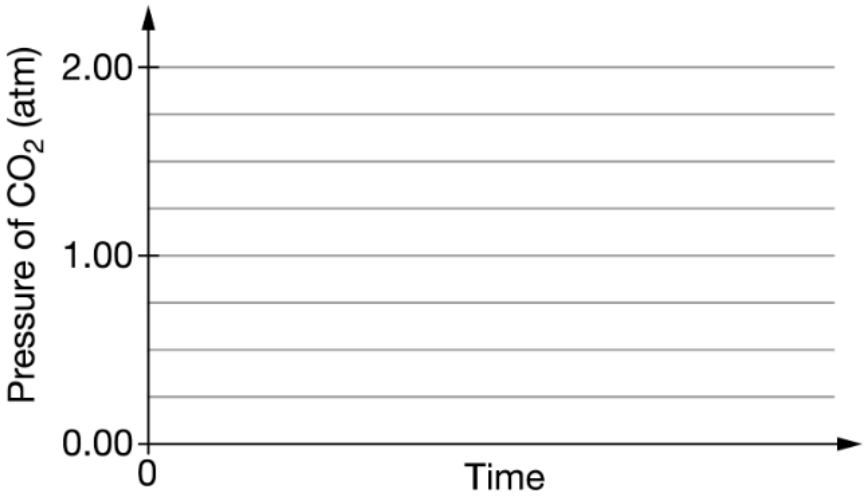
$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

3. When heated strongly, solid calcium carbonate decomposes to produce solid calcium oxide and carbon dioxide gas, as represented by the equation above. A 2.0 mol sample of $CaCO_3(s)$ is placed in a rigid 100. L reaction vessel from which all the air has been evacuated. The vessel is heated to 898°C at which time the pressure of $CO_2(g)$ in the vessel is constant at 1.00 atm.

   a. Calculate the number of moles of $CO_2(g)$ present in the vessel at equilibrium.

   b. Write the expression for K_p, the equilibrium constant for the reaction, and determine its value at 898°C.

   c. The experiment was repeated, but this time starting with a 4.0 mol sample of $CaCO_3(s)$. On the following graph, draw a curve showing how the pressure of $CO_2(g)$ would change over time as the vessel is heated to 898°C and equilibrium is established.



4. Sulfuryl chloride, SO_2Cl_2, is a highly reactive gaseous compound. When heated, it decomposes as follows.

$$SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g)$$

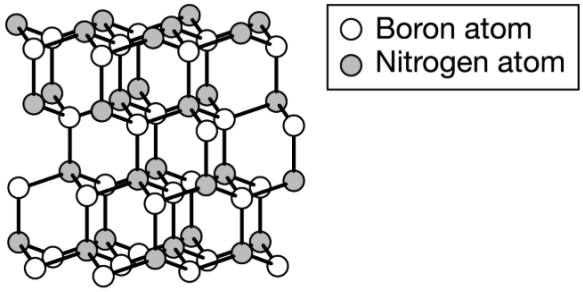
A sample of 3.509 grams of SO_2Cl_2 is placed in an evacuated 1.00-liter bulb and the temperature is raised to 375 K.

   a. What would be the pressure in atmospheres in the bulb if no dissociation of the $SO_2Cl_2(g)$ occurred?

   b. When the system has come to equilibrium at 375 K, the total pressure in the bulb is found to be 1.43 atmospheres. Calculate the partial pressures of SO_2, Cl_2, and SO_2Cl_2 at equilibrium at 375 K.

   c. Give the expression for the equilibrium constant, K_p, for the decomposition of $SO_2Cl_2(g)$ at 375 K and calculate the value of K_p.

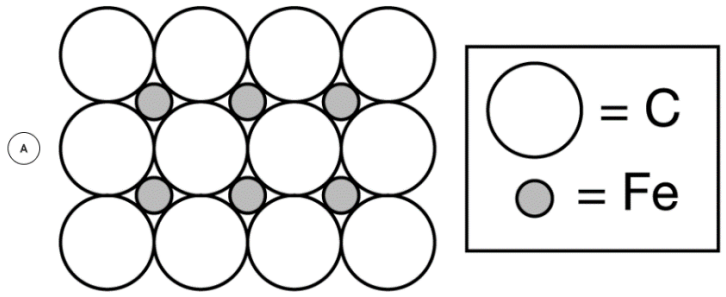
   d. If the temperature were raised to 500 K, what effect would this have on the equilibrium constant? Explain briefly.

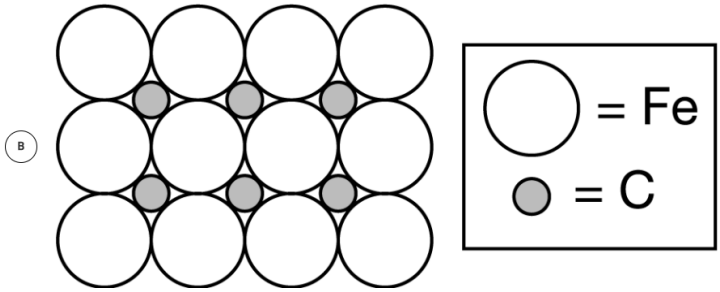


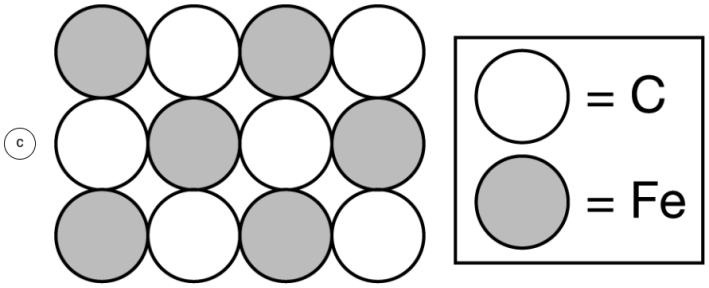
Cubic Form of
Boron Nitride

5. The structure of one form of boron nitride is represented above. In this structure, molecules are bonded to other molecules by covalent bonds. This form of boron nitride is one of the hardest substances known. Explain why based on the principles of types of solids and bonding.

6. Steel is an alloy of Fe and C atoms. Which diagram best represents the particle-level structure of steel? Justify your answer in terms of atomic structure.







7. The lattice energy of a salt is related to the energy required to separate the ions. Arrange the salts below in order of increasing boiling point based on their lattice energies. Justify your order based on the Coulomb's law.

CaO NaCl CsBr MgO

8. Use the information in the chart to answer the questions that follow.

	Solid A	Solid B	Solid C	Solid D
Solid conducts electricity	Yes	No	No	No
Soluble in water	No	Yes	No	Yes
Aqueous solution conducts electricity	Not soluble	Yes	Not soluble	No
Relative melting point	High	High	Very high	Low

a. Identify the type of bonding present in each solid based on the data in the table. **Carefully explain how the data led to your conclusions.**

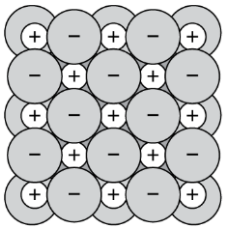
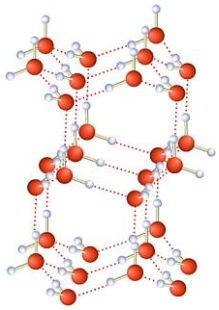
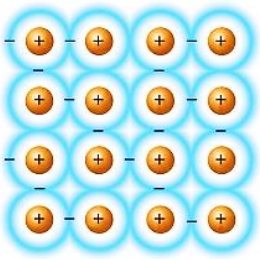
i. Solid A: _____

ii. Solid B: _____

iii. Solid C: _____

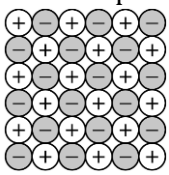
iv. Solid D: _____

b. Match each particle representation below with the correct solid.


c. Metals are ductile and malleable, and they are conductors of heat and electricity. Explain these properties of metals based on their particulate structures.

d. If the solid represented below is hit with a hammer, what occurs on a macroscopic and microscopic level? Explain your answer.



e. Diamond and graphite are both allotropes of carbon, yet their physical properties are very different. Diamonds have a hard cuboidal structure, whereas graphic is much softer and is used as a lubricant. Using the particle representation of graphite below, explain why the properties of graphite are different than those of diamond.