AP* Gas Law Free Response Questions

1971

$$2\ HCOONa + H_2SO_4 \rightarrow 2\ CO + 2\ H_2O + Na_2SO_4$$

A 0.964 gram sample of a mixture of sodium formate and sodium chloride is analyzed by adding sulfuric acid. The equation for the reaction for sodium formate with sulfuric acid is shown above. The carbon monoxide formed measures 242 milliliters when collected over water at 752 torr and 22.0°C. Calculate the percentage of sodium formate in the original mixture.

1971

At 20°C the vapor pressure of benzene is 75 torr, and the vapor pressure of toluene is 22 torr. Solutions in both parts of this question are to be considered ideal.

(a) A solution is prepared from 1.0 mole of biphenyl, a nonvolatile solute, and 49.0 moles of benzene. Calculate the vapor pressure of the solution at 20°C.

(b) A second solution is prepared from 3.0 moles of toluene and 1.0 mole of benzene. Determine the vapor pressure of this solution and the mole fraction of benzene in the vapor.

1972

A 5.00 gram sample of a dry mixture of potassium hydroxide, potassium carbonate, and potassium chloride is reacted with 0.100 liter of 2.0 molar HCl solution.

(a) A 249 milliliter sample of dry CO_2 gas, measured at 22°C and 740 torr, is obtained from the reaction. What is the percentage of potassium carbonate in the mixture?

(b) The excess HCl is found by titration to be chemically equivalent to 86.6 milliliters of 1.50 molar NaOH. Calculate the percentages of potassium hydroxide and of potassium chloride in the original mixture.

1973

A 6.19 gram sample of PCl_5 is placed in an evacuated 2.00 liter flask and is completely vaporized at 252°C.

(a) Calculate the pressure in the flask if no chemical reaction were to occur.

(b) Actually at 252°C the PCl_5 is partially dissociated according to the following equation:

$$PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$$

The observed pressure is found to be 1.00 atmosphere. In view of this observation, calculate the partial pressure of PCl_5 and PCl_3 in the flask at 252°C.

1976

When the molecular weight of a volatile liquid is calculated from the weight, volume, temperature, and pressure of a sample of that liquid when vaporized, the assumption is usually made that the gas behaves ideally. In fact at a temperature not far above the boiling point of the liquid, the gas is not ideal. Explain how this would affect the results of the molecular weight determination.

1982

(a) From the standpoint of the kinetic-molecular theory, discuss briefly the properties of gas molecules that cause deviations from ideal behavior.

(b) At 25°C and 1 atmosphere pressure, which of the following gases shows the greatest deviation from ideal behavior? Give two reasons for your choice.

CH_4 SO_2 O_2 H_2

(c) Real gases approach ideality at low pressure, high temperature, or both. Explain these observations.

1984

The van der Waals equation of state for one mole of a real gas is as follows:

$$(P + {}^{a}/_{V^2})(V - b) = RT$$

For any given gas, the values of the constants *a* and *b* can be determined experimentally. Indicate which physical properties of a molecule determine the magnitudes of the constants a and b. Which of the two molecules, H_2 or H_2S, has the higher value for *a* and which has the higher value for *b*? Explain.

One of the van der Waals constants can be correlated with the boiling point of a substance. Specify which constant and how it is related to the boiling point.

1986

Three volatile compounds X, Y, and Z each contain element Q. The percent by weight of element Q in each compound was determined. Some of the data obtained are given below.

Compound	Percent by Weight of Element Q	Molecular Weight
X	64.8%	?
Y	73.0%	104.
Z	59.3%	64.0

(a) The vapor density of compound X at 27 degrees Celsius and 750. mm Hg was determined to be 3.53 grams per liter. Calculate the molecular weight of compound X.

(b) Determine the mass of element Q contained in 1.00 mole of each of the three compounds.

(c) Calculate the most probable value of the atomic weight of element Q.

(d) Compound Z contains carbon, hydrogen, and element Q. When 1.00 gram of compound Z is oxidized and all of the carbon and hydrogen are converted to oxides, 1.37 grams of CO_2 and 0.281 gram of water are produced. Determine the most probable molecular formula.

1990

A mixture of $H_2(g)$, $O_2(g)$, and 2 millilitres of $H_2O(l)$ is present in a 0.500 litre 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 is 1,146 millimetres mercury. (The equilibrium vapor pressure of pure water at 25°C is 24 millimetres mercury.)

The mixture is sparked, and H_2 and O_2 react until one reactant is completely consumed.

(a) Identify the reactant remaining and calculate the number of moles of the reactant remaining.

(b) 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 millimetres mercury.)

(c) Calculate the number of moles of water present <u>as vapor</u> in the container at 90°C.

1993

Observations about real gases can be explained at the molecular level according to the kinetic molecular theory of gases and ideas about intermolecular forces. Explain how each of the following observations can be interpreted according to these concepts, including how the observation supports the correctness of these theories.

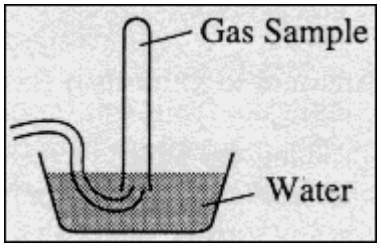
(a) When a gas-filled balloon is cooled, it shrinks in volume; this occurs no matter what gas is originally placed in the balloon.

(b) When the balloon described in (a) is cooled further, the volume does not become zero; rather, the gas becomes a liquid or solid.

(c) When NH_3 gas is introduced at one end of a long tube while HCl gas is introduced simultaneously at the other end, a ring of white ammonium chloride is observed to form in the tube after a few minutes. This ring is closer to the HCl end of the tube than the NH_3 end.

(d) A flag waves in the wind.

1994



A student collected a sample of hydrogen gas by the displacement of water as shown by the diagram above. The relevant data are given in the following table.

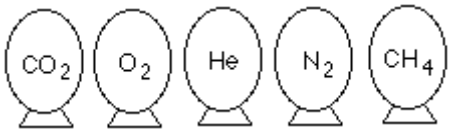
GAS SAMPLE DATA	
Volume of sample	90.0 mL
Temperature	25°C
Atmospheric Pressure	745 mm Hg
Equilibrium Vapor Pressure of H_2O (25°C)	23.8 mm Hg

(a) Calculate the number of moles of hydrogen gas collected.
(b) Calculate the number of molecules of water vapor in the sample of gas.
(c) Calculate the ratio of the average speed of the hydrogen molecules to the average speed of the water vapor molecules in the sample.
(d) Which of the two gases, H_2 or H_2O, deviates more from ideal behavior? Explain your answer.

1995

Propane, C_3H_8, is a hydrocarbon that is commonly used as fuel for cooking.
(a) Write a balanced equation for the complete combustion of propane gas, which yields $CO2(g)$ and $H_2O(l)$.
(b) Calculate the volume of air at 30°C and 1.00 atmosphere that is needed to burn completely 10.0 grams of propane. Assume that air is 21.0 percent O_2 by volume.
(c) The heat of combustion of propane is −2,220.1 kJ/mol. Calculate the heat of formation, ΔH_f^o, of propane given that ΔH_f^o of $H_2O(l)$ = −285.3 kJ/mol and ΔH_f^o of $CO_2(g)$ = −393.5 kJ/mol.
(d) Assuming that all of the heat evolved in burning 30.0 grams of propane is transferred to 8.00 kilograms of water (specific heat = 4.18 J/g·K), calculate the increase in temperature of water.

1996



Represented above are five identical balloons, each filled to the same volume at 25°C and 1.0 atmosphere pressure with the pure gas indicated.

(a) Which balloon contains the greatest mass of gas? Explain.

(b) Compare the average kinetic energies of the gas molecules in the balloons. Explain.

(c) Which balloon contains the gas that would be expected to deviate most from the behavior of an ideal gas? Explain.

(d) Twelve hours after being filled, all the balloons have decreased in size. Predict which balloon will be the smallest. Explain your reasoning.

2002B

A rigid 8.20 L flask contains a mixture of 2.50 moles of H_2, 0.500 mole of O_2, and sufficient Ar so that the partial pressure of Ar in the flask is 2.00 atm. The temperature is 127ºC.

(a) Calculate the total pressure in the flask.
(b) Calculate the mole fraction of H_2 in the flask.
(c) Calculate the density (in g L^{-1}) of the mixture in the flask.

The mixture in the flask is ignited by a spark, and the reaction represented below occurs until one of the reactants is entirely consumed.

$$2\ H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

(d) Give the mole fraction of all species present in the flask at the end of the reaction.