Additional Test Review

Sample Problem

How many moles of oxygen are consumed when 0.6 moles of hydrogen burns to produce water?

Step 1: Write a balanced equation and determine the mole ratios from the equation

Step 2: Identify the known and the unknown

	$2\,H_2(g)$	$+\ O_2(g)$	$\rightarrow 2\,H_2O$
mole ratio	2	1	2
moles	known 0.6	unknown x	

Step 3: Set up a proportion and solve for the unknown

- $\frac{2}{0.6mol} = \frac{1}{x}$
- $2x = 0.6mol$
- $x = 0.3mol$

Stoichiometry. Stoichiometry is the branch of chemistry that deals with the application of the laws of definite proportions and of the conservation of mass and energy to chemical activity. It shows the quantitative relationship between constituents of a chemical reaction. Stoichiometric calculations are based on several assumptions. It is assumed that the reaction has no side reactions, the reaction goes to completion, and the reactants are completely consumed. One type of problem that can be solved stoichiometrically is based on the mole ratios of a balanced equation. A sample problem is shown to the left.

Mass/Mass Problems. With a balanced equation, a *Periodic Table*, and some knowledge of chemistry, you can figure out how much of any product will form from a given amount of reactant. There is a sample problem below solved by the factor label method. You will notice that, in applying the factor label method, you are first converting grams of the known to moles, then moles of the known to moles of the unknown using a proportion from the coefficients of the balanced equation, and, finally, moles of the unknown to grams as shown above. You can use the equations to the lower right instead of using the factor label method.

How much oxygen is needed to produce 27.0 g of water by burning hydrogen?

Step 1: Write a balanced equation
$2H_2 + O_2 \rightarrow 2H_2O$

Step 2: Calculate the GFM of the known and unknown.

O_2
O = 16 × 2 = 32

H_2O
H = 1 × 2 = 2
O = 16 × 1 = 16
18

Step 3: Apply the factor label method

$$27g_{H_2O} \times \frac{1\,mol_{H_2O}}{18\,g_{H_2O}} \times \frac{1\,mol_{O_2}}{2\,mol_{H_2O}} \times \frac{32\,g_{O_2}}{1\,mol_{O_2}} = 24\,g_{O_2}$$

$$Grams_{KNOWN} \xrightarrow{STEP\,1} Moles_{KNOWN} \xrightarrow{STEP\,2} Moles_{UNKNOWN} \xrightarrow{STEP\,3} Grams_{UNKNOWN}$$

- *STEP* 1: $moles = \frac{g}{GFM}$
- *STEP* 2: $\frac{Moles_{KNOWN}}{Coefficient_{KNOWN}} = \frac{x}{Coefficient_{UNKNOWN}}$
- *STEP* 3: $g = moles \times GFM$

Limiting Reactants and Percent Yield. The reactants that get used up first are limiting reactants. The limiting reactants can be used to predict the theoretical yield. The percent yield is determined by comparing the theoretical yield to the actual yield. See below.

Sample Problem

If 68.5 kg of CO reacts with 8.60 kg of H_2 to produce 35.7 kg of CH_3OH, what is the percent yield?

Step 1: Write a balanced equation.

$2H_2(g) + CO(g) \rightarrow CH_3OH(\ell)$

Step 2: Identify the limiting reactant by calculating the actual number of moles of each reactant. Then divide each by its coefficient. The smaller result is the limiting reactant.

$$68.5kg\ \mathrm{CO} \times \frac{1000g}{1kg} \times \frac{1mol\ \mathrm{CO}}{28.01g\ \mathrm{CO}} = 2.45 \times 10^3 mol\ \mathrm{CO}$$

$$8.60kg\ \mathrm{H_2} \times \frac{1000g}{1kg} \times \frac{1mol\ \mathrm{H_2}}{2.016g\ \mathrm{H_2}} = 4.27 \times 10^3 mol\ \mathrm{H_2}$$

$$\frac{2.45 \times 10^3 mol\ \mathrm{CO}}{1} = 2.45 \times 10^3 mol\ \mathrm{CO} \qquad \frac{4.27 \times 10^3 mol\ \mathrm{H_2}}{2} = 2.14 \times 10^3 mol\ \mathrm{H_2}$$

Since 2.14×10^3 mol of H_2 is the smaller value, H_2 is the limiting reactant.

Step 3: Use the limiting reactant to complete the calculation of the theoretical yield.

$$4.27 \times 10^3 mol\ \mathrm{H_2} \times \frac{1mol\ \mathrm{CH_3OH}}{2mol\ \mathrm{H_2}} \times \frac{32.04g\ \mathrm{CH_3OH}}{1mol\ \mathrm{CH_3OH}} \times \frac{1kg}{1000g} = 68.4kg\ \mathrm{CH_3OH}$$

Step 4: Calculate the percent yield by comparing the actual to the theoretical.

$$\frac{35.7kg\ \mathrm{CH_3OH}}{68.4kg\ \mathrm{CH_3OH}} \times 100\% = 52.2\%$$

ENERGY

Calculating Joules. When you heat a solid, it's temperature generally goes up. There is a relationship between heat and temperature, but they are not the same thing. It would take a lot more energy to heat up the ocean than to warm a cup of tea. The ocean has a larger mass. It has many more molecules to share energy with. Mass is not the only thing that influences the way the temperature changes in response to heat. When the same sun beats down on the beach, the sand gets a lot hotter than the water. Water has a higher heat capacity than sand. The relationship between mass, temperature change, specific heat, and energy are shown to the right.

Specific Heat. Some substances are more resistant to temperature change than others. They have a higher specific heat. The equation for determining specific heat is shown to the right

Temperature scales. The Celsius scale is based on water. The freezing point of water is 0°C, while the boiling point of water is 100°C. The Kelvin scale is based on the Celsius scale with the zero at absolute zero. Absolute zero is the lowest possible temperature. It is the temperature at which particles of matter stop moving.

K = °C + 273 and **°C = K – 273**

$$\mathbf{Q = mC_p\Delta T}$$

Q = heat (J) m = mass in grams

ΔT = change in temperature [$\Delta T = T_f - T_i$]

T_f = final temperature

T_i = starting temperature

C_p = 4.18 J/g°C for water

$$C_p = \frac{Q}{m\Delta T}$$

Q = joules; m = mass in grams

ΔT = change in temperature [$\Delta T = T_f - T_i$]

T_f = final temperature (°C)

T_i = starting temperature (°C)

C_p = specific heat (J/g°C)

PHASES OF MATTER

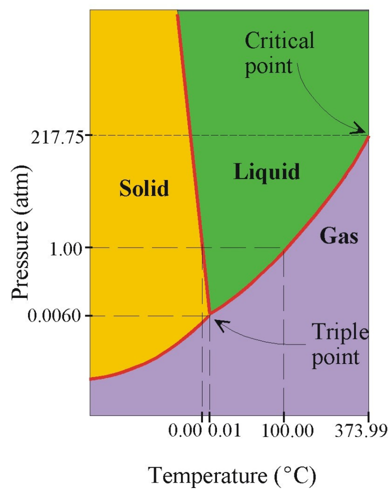
Comparing Solids, Liquids, and Gases. Solids are substances with a definite shape and volume. The particles of solids vibrate about fixed positions, held in place by large forces of attraction. Liquids have a definite volume, but their shape is determined by their container. The particles of a liquid roll and slide over each other. Both the shape and volume of a gas are determined by the container. This is because the particles move independently, and spread out to fill the container. Gases are mostly empty space, and they can be compressed.

Kinetic Molecular Theory. Matter is composed of particles that are in constant motion (kinetic energy). There are forces of attraction between particles that depend on the distance between the particles. The further apart the particles are, the smaller the forces of attraction between them are. The higher the temperature (average kinetic energy) is, the faster the particles move. The *Kinetic Molecular Theory* explains the phases. In solids the forces of attraction between particles are larger than in other phases. As a result, the particles are held relatively close together in fixed positions, vibrating back and forth. Therefor the shape and volume are not determined by the container. In liquids the forces of attraction between particles are moderate compared to other phases. The particles can move from place to place but cannot separate from each other and move independently, so they roll and slide over each other. The particles are pulled downhill by gravity causing the liquid to seek its own level, so the shape is determined by the container but the volume is not. In gases the forces of attraction between particles are weaker than in other phases. The particles can move from place to place independently of each other because they do NOT attract or repel each other. The particles are relatively far apart. The volume of the particles is small compared to the space between them. Gases tend to spread out to fill their container. Therefor both the shape and volume are determined by the container.

PHASE CHANGES

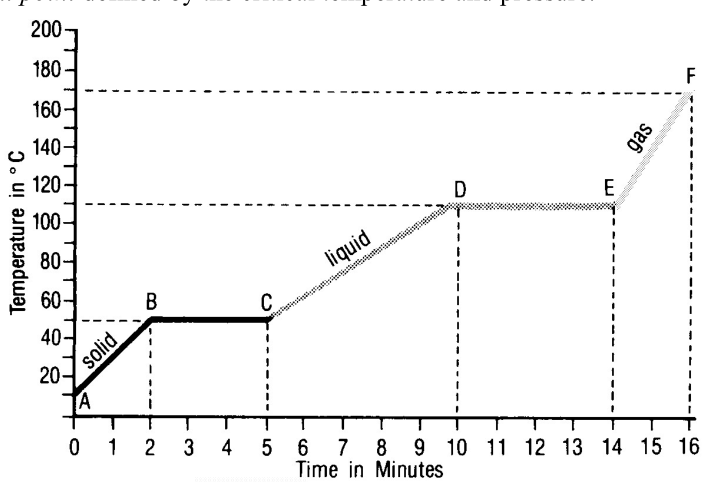
Heating a substance in a given phase causes the temperature to increase. Increasing the temperature causes particles to move faster and collide harder. This causes the particles to rebound harder moving them further apart. Larger distances between particles weakens the forces of attraction between them. When the forces of attraction are weak enough, the distance between the particles increases markedly and the phase changes. As a result, a solid melts, and a liquid evaporates. The reverse happens when a substance cools, so a gas condenses, and a liquid freezes.

Phase Diagram. A phase diagram shows phases of a substance in a closed system as a function of temperature and pressure. The points on the phase diagram are [a] the *triple point* where all three phases of mater coexist; [b] the *critical temperature* above which vapor cannot be liquefied no matter what pressure is applied; [c] the *critical pressure*, the pressure required to form a liquid at the critical temperature; and [d] the *critical point* defined by the critical temperature and pressure.



Phase diagram for water

Heating/Cooling Curve. The temperature does not change during a phase change. The heat energy absorbed or lost does not result in a change in kinetic energy. Instead, there is a change in potential energy due to the change in distance between the particles. The *Freezing/Melting point* is the temperature at which the solid and liquid phase exist in equilibrium. The *heat of fusion* is the amount of heat needed to change a unit mass of a substance from a solid to a liquid at a constant temperature and 1 atm of pressure. For water it is 333.6 J/g. The *boiling point* is the temperature at which the vapor pressure is equal to the surrounding pressure. The *heat of vaporization* is the amount of heat needed to change a unit mass of a substance from a liquid to a gas at a constant temperature and 1 atm of pressure. For water it is 2259 J/g.



Heating/Cooling Curve

Vapor Pressure. When water evaporates, it changes from a liquid to a gas called water vapor. Water vapor takes up more space than an equal mass of liquid water. As a result, in a closed container, the vapor that forms can exert a significant amount of pressure. This pressure is known as vapor pressure. Even in an open container, the vapor is confined by the air pressing down on it. Some of it collects at the surface and exerts pressure. Occasional high energy molecules at the water's surface escape. That is why the water eventually evaporates. But for a water to expand and form vapor bubbles throughout the liquid as it does when it boils, the vapor has to exert as much pressure as the blanket of air confining it. As a liquid is heated, more of it turns into vapor, and the vapor pressure increases. When the vapor pressure reaches atmospheric pressure, the liquid boils. Under greater external pressure, the liquid boils at a higher temperature.

GAS LAWS

There are a number of relationships between the pressure, volume, temperature, and the number of moles of a gas: Boyle's law says the volume of a gas is inversely proportional to the pressure at a constant temperature [$\mathbf{V} \propto {}^{1}/_{\mathbf{P}}$]; Charles law says at a constant pressure, the volume of a gas is directly proportional to its Kelvin temperature [$\mathbf{V} \propto \mathbf{T}$]; Avogadro's law says that at constant temperature, the volume of a gas is directly proportional to the number moles [$\mathbf{V} \propto \boldsymbol{n}$]; and finally Gay-Lussac's law says for a gas at constant volume, the temperature and pressure are directly proportional [$\mathbf{T} \propto \mathbf{P}$]. For a constant number of moles, the combined gas law provides the relationship between the temperature, pressure, and volume of a gas as any of these variables changes. The ideal gas law gives the relationship among all the variables of Boyle's, Charles, and Avogadro's laws..

Ideal Gas Law

$$PV = nRT$$

$$R = 0.0821 \frac{L \cdot atm}{mol.K}$$

Applications of Avogadro's Law. The volume of 1 mole of gas at STP (Standard Temperature and Pressure) is always 22.4 L. Standard temperature is 0 °C or 273 K. Standard pressure is 1 atm, 101.3 kPa, or 760 mm Hg. Using the standard molar volume, it is possible to solve several types of problems. See below

Sample Problem 1: Moles to Volume

How many liters do 3.50 moles of oxygen occupy at STP?

$$3.50 mol \left(\frac{22.4 L}{1 mol}\right) = 78.4 L$$

Sample Problem 2: Volume to Moles

How many moles of nitrogen occupy 186 *L* at STP?

$$186 L \left(\frac{1 mol}{22.4 L}\right) = 8.30 mol$$

Sample Problem 3: Grams to Volume

What is the volume of 84.21 g of methane (CH_4) at STP?

$$84.21 g \left(\frac{1 mol}{16.04 g}\right)\left(\frac{22.4 L}{1 mol}\right) = 118 L$$

Sample Problem 4: Volume to Grams

What is the mass of 25.0 *mL* of dinitrogen trioxide (N_2O_3) at STP?

$$25.0 mL \left(\frac{1 L}{1000 mL}\right)\left(\frac{1 mol}{22.4 L}\right)\left(\frac{76.02 g}{1 mol}\right) = 8.48 \times 10^{-2} g$$

of the Combined Gas Law. The combined gas law has 6 variables. Any of the variables can be determined if 5 are known.

Sample Problem

A gas with a volume of 250. mL at 35 °C and 101.3 kPa is heated to 57 °C and the pressure is increased to 151.3 kPa. What is its new volume?

- $T_1 = 35 + 273 = 308 K;\ T_2 = 57 + 273 = 330 K$
- $\dfrac{P_1 V_1}{T_1} = \dfrac{P_2 V_2}{T_2}$
- $V_2 = \dfrac{P_1 V_1 T_2}{T_1 P_2} = \dfrac{(101.3 kPa)(250 mL)(330 K)}{(308 K)(151.3 kPa)} = 179 mL$

Applications of the Ideal Gas Law.

Sample Problem

What is the volume of 6.06 g of hydrogen at 27 °C and 1.50 atm?

$$PV = nRT \quad \therefore \quad V = \frac{nRT}{P}$$

$$6.06 g \left(\frac{1 mol}{2.02 g}\right) = 3.00 mol$$

$$V = \frac{(3.00 mol)(0.0821 \frac{L \cdot atm}{mol \cdot K})(300.\ K)}{1.50 atm} = 49.3 L$$

Assumptions of the Ideal Gas Law. This Ideal Gas model is based on the following assumptions, and can be applied only under conditions of low pressure and high temperature: (1) gas molecules are continuously moving in a random, straight line motion. (2) when gas molecules collide with each other or with the walls of the container there is no energy lost. Therefore, the total energy of the system never changes. (3) the actual volume of the molecules is insignificant when compared to the volume of the contained area (the container). (4) no attraction exists between molecules. Gases deviate from the ideal conditions when conditions of high pressure and low temperature exist. These conditions lead to confinement and intermolecular attractions begin to act. In fact, gas molecules do have a volume of their own, and there are forces of attraction between gas molecules. The factors allow for the existence of gases as either solids or liquids under certain conditions,

Gas Stoichiometry. Since the ideal gas law makes it possible to calculate the number of moles of a gas contained in a given volume of gas, it is possible to do the same type of calculations based on a balanced equation that one does with masses.

$$\begin{tikzcd} mass_1 \arrow[dr] & & & mass_2 \\ & moles_1 \arrow[r] & moles_2 \arrow[ur] \arrow[dr] & \\ volume_1 \arrow[ur] & & & volume_2 \end{tikzcd}$$

Sample Problem 1

How many grams of rust (Fe_2O_3) form when iron reacts with 25.0 L of oxygen at 25 °C and 200. kPa?

Step 1: Write a balanced equation

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Step 2: Substitute values into the gas equation to get the number of moles of gas

$$n = \frac{PV}{RT} = \frac{(200.\,kPa)(1atm)(25.0L)}{(101.3kPa)(0.0821\,\frac{L\cdot atm}{mol\cdot K})(298K)} = 2.02mol$$

Step 3: Solve the remaining problem by the factor label method.

$$2.02mol_{O_2}\left(\frac{2mol_{Fe_2O_3}}{3mol_{O_2}}\right)\left(\frac{159.7g_{Fe_2O_3}}{1mol_{Fe_2O_3}}\right) = 215g_{Fe_2O_3}$$

Sample Problem 2

How many milliliters of ammonia are formed when 150.mL of hydrogen combines with nitrogen at constant temperature and pressure?

Step 1: Write a balanced equation

$N_2 + 3H_2 \rightarrow 2NH_3$

Step 2: Set up a proportion and solve

$$\frac{3mol_{H_2}}{150.ml_{H_2}} = \frac{2mol_{NH_3}}{x} \qquad x = 100ml_{NH_3}$$

Sample Problem 3

How many liters of oxygen are liberated when 18.4 g of potassium chlorate decompose at STP?

Step 1: Write a balanced equation.

$2KClO_3 \rightarrow 2KCl + 3O_2$

Step 2: Solve by the factor label method

$$18.4g_{KClO_3}\left(\frac{1mol_{KClO_3}}{122.6g_{KClO_3}}\right)\left(\frac{3mol_{O_2}}{2mol_{KClO_3}}\right)\left(\frac{22.4L_{O_2}}{1mol_{O_2}}\right) = 5.04L$$

Answer the questions below by circling the number of the correct response

1. Given the balanced equation: $NaOH + HCl \rightarrow NaCl + H_2O$, what is the total number of grams of H_2O produced when 116 grams of the product, NaCl, is formed? (1) 9.0 g (2) 18 g (3) 36 g (4) 54 g

2. Given the reaction: $4Al + 3O_2 \rightarrow 2Al_2O_3$
How many moles of Al_2O_3 will be formed when 27 grams of Al reacts completely with O_2? (1) 1.0 (2) 2.0 (3) 0.50 (4) 4.0

3. A 6.32-g sample of potassium chlorate is decomposed according to the following equation:
$$2KClO_3 \rightarrow 2KCl + 3O_2$$
How many moles of oxygen are formed? (1) 1.65 g (2) 0.051 moles (3) 0.0344 moles (4) 0.0774 moles (5) none of these

4. If 300.0 kg of iron ore are reacts with 200.0 kg of carbon monoxide to produce 100.0 kg of pure iron,[$Fe_2O_3(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$] what is the percent yield? (1) 47.64 % (2) 23.82 % (3) 71.46 % (4) 95.28 %

5. Suppose the reaction,
$Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow 3CaSO_4 + 2H_3PO_4$,
is carried out starting with 103 g of $Ca_3(PO_4)_2$ and 75.0 g of H_2SO_4. Which substance is the limiting reactant? (1) $Ca_3(PO_4)_2$ (2) H_2SO_4 (3) $CaSO_4$ (4) H_3PO_4 (5) none of these

6. How many grams of H_2O will be formed when 32.0 g H_2 is mixed with 32.0 g O_2 and allowed to react to form water? (1) 36.0 g (2) 288 g (3) 18.0 g (4) 64.0 g (5) 144 g

7. The reaction of 11.9 g of $CHCl_3$ with excess chlorine produced 12.6 g of CCl_4 , carbon tetrachloride:
$CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$.
What is the percent yield? (1) 100% (2) 27.4% (3) 82.2% (4) 113% (5) 46.2%

8. Consider the following reaction:
$CH_4(g) + 4Cl_2(g) \rightarrow CCl_4(g) + 4HCl(g)$.
What mass of CCl_4 will be formed if 1.20 moles of methane react with 1.60 moles of chlorine? (1) 229 g (2) 171 g (3) 114 g (4) 61.5 g (5) 17.1 g

9. Which temperature represents absolute zero? (1) 0 K (2) 0°C (3) 273 K (4) 273°C

10. At which temperature does a water sample have the highest average kinetic energy (1) 0°C, (2) 100°C, (3) 0 K, (4) 100 K

11. When 84 joules of heat is added to 2.0 gram of water at 15°C, the temperature of the water increases to (1) 5.0°C, (2) 15°C, (3) 25°C, (4) 50. 0 C

12. Which Kelvin temperatures represent, respectively, the normal freezing point and the normal boiling point of water? (1) 0 K and 273 K (2) 0 K and 100 K (3) 100 K and 273 K (4) 273 K and 373 K

13. How many joules of heat energy are released when 50 grams of water are cooled from 70°C to 60°C? (1) 42 joules (2) 209 joules (3) 2090 joules (4) 4,180 joules

14. The number of joules needed to raise the temperature of 10 grams of' water from 20°C to 30°C is (1) 42, (2) 84, (3) 418, (4) 167

15. A 5-gram sample of water is heated and the temperature rises from 10°C to 15°C. The total amount of heat energy absorbed by the water is (1) 105 J, (2) 84 J, (3) 63 J, (4) 21 J

16. At which temperature would the molecules in a one gram sample of water have the lowest average kinetic energy? (1) 5°C (2) –100°C (3) 5 K (4) 100 K

17. How many kilojoules of heat energy are absorbed when 100 grams of water is heated from 20°C to 30°C? (1) 4.18 kJ (2) 41.8 kJ (3) 418 kJ (4) 0.418 kJ

18. The temperature of a substance changes from -173°C to 0°C. How many Kelvin degrees does this change represent? (1) 100. (2) 173 (3) 273 (4) 446

19. How many kilojoules of heat are needed to raise the temperature of 500. grams of water from 10.0°C to 30.0°C? (1) 41.8 kJ (2) 105kJ (3) 209. kJ (4) 167 kJ

20. When 5 grams of water at 20°C absorbs 10 joules of heat, the temperature of the water will be increased by a total of (1) 0. 5 C° (2) 2 C° (3) 10 C° (4) 50 C°

21. Which Kelvin temperature is equal to –33°C? (1) –33 K (2) 33 K (3) 240 K (4) 306 K

22. If 4 grams of water at 1°C absorbs 33.6 joules of heat, the temperature of the water will change by (1) 1 C° 2) 2 C° (3) 3 C° (4) 4 C°

23. The molecules of which substance have the highest average kinetic energy? (1) He(g) at 0°C (2) $CO_2(g)$ at 20°C (3) HCl(g) at 40°C (4) $N_2(g)$ at 60°C

24. Which 5.0-milliliter sample of NH_3 will take the shape of and completely fill a closed 100.0-milliliter container? (1) $NH_3(s)$ (2) $NH_3(\ell)$ (3) $NH_3(g)$ (4) $NH_3(aq)$

25. Which of the following has the strongest forces of attraction? (1) $CO_2(s)$ (2) $CO_2(\ell)$ (3) $CO_2(g)$ (4) $CO_2(aq)$

26. Which of the following can be compressed under pressure? (1) $I_2(s)$ (2) $I_2(\ell)$ (3) $I_2(g)$ (4) $I_2(aq)$

27. Which 1.5-liter sample of salt does *NOT* take the shape of its container? (1) NaCl(s) (2) NaCl(ℓ) (3) NaCl(g) (4) NaCl(aq)

28. A 25.0 mL sample of water is poured from a 50.0 mL graduated cylinder to a 100.0 mL graduated cylinder. The volume of the water (1) increases, (2) decreases, (3) remains the same.

29. As ice melts at standard pressure, its temperature remains at 0°C until it has completely melted. Its potential energy (1) decreases (2) increases (3) remains the same

30. When water freezes, each gram loses an amount of heat equal to its heat of (1) fusion (2) vaporization (3) sublimation (4) reaction

31. As the temperature of a liquid increases, its vapor pressure (1) decreases (2) increases (3) remains the same

32. Which change of phase represents vaporization? (1) gas to liquid (2) gas to solid (3) solid to liquid (4) solid to gas

33. Which substance readily sublimes at room temperature? (1) $H_2O(\ell)$ (2) $O_2(g)$ (3) Fe(s) (4) $CO_2(s)$

34. Which change of phase represents sublimation? (1) $H_2O(g) \rightarrow H_2O(\ell)$ (2) $H_2O(\ell) \rightarrow H_2O(s)$ (3) $CO_2(s) \rightarrow CO_2(g)$ (4) $CO_2(s) \rightarrow CO_2(\ell)$

35. Which change of phase is exothermic? (1) gas to liquid (2) solid to liquid (3) solid to gas (4) liquid to gas

36. The heat of fusion for ice is 333.6 joules per gram. Adding 333.6 joules of heat to one gram of ice at STP will cause the ice to (1) increase in temperature (2) decrease in temperature (3) change to water at a higher temperature (4) change to water at the same temperature

37. Which term represents the change of a substance from the solid phase to the liquid phase? (1) condensation (2) vaporization (3) evaporation (4) fusion

38. When the vapor pressure of a liquid in an open container equals the atmospheric pressure, the liquid will (1) freeze (2) crystallize (3) melt (4) boil

39. The energy required to change a unit mass of a liquid to a gas at constant temperature is called its heat of (1) formation (2) vaporization (3) combustion (4) fusion

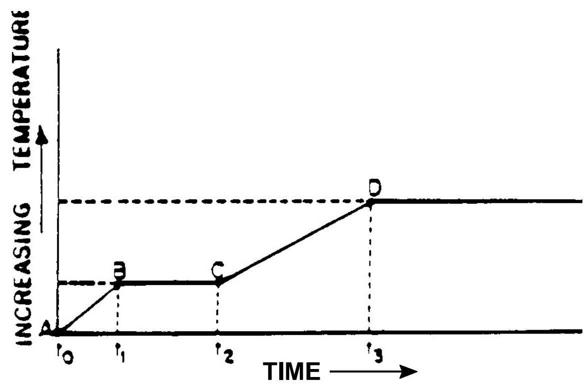
40. Which sample contains particles arranged in regular geometric pattern? (1) $CO_2(\ell)$ (2) $CO_2(s)$ (3) $CO_2(g)$ (4) $CO_2(aq)$

41. The heat of fusion of a substance is the energy measured during a (1) phase change (2) temperature change (3) chemical change (4) pressure change

42. A substance sublimes at standard temperature and pressure. What could be done to cause the substance to melt? (1) increase the temperature (2) decrease the temperature (3) increase the pressure (4) decrease the pressure.

43. The temperature at which a substance can exist as a solid, liquid, and gas simultaneously is the (1) melting point, (2) triple point, (3) boiling point, (4) critical point.

Base your answers to questions 44 and 45 on the diagram below which represents a substance being from a solid to a gas, the pressure remaining constant



44. The substance begins to boil at point (1) A (2) B (3) C (4) D

45. Between points B and C the substance exists in (1) the solid state, only (2) the liquid state, only (3) both the solid and liquid states (4) neither the solid nor the liquid state

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Answer questions 46-48 by referring to Table H on the reference tables.

46. At what pressure will ethanol boil at 90°C? (1) 75 kPa (2) 150 kPa (3) 101.3 kPa (4) 200 kPa

47. At what temperature will water boil at a pressure of 10 kPa? (1) 25°C (2) 10°C (3) 101.3°C (4) 45°C

48. Which of the following has the highest boiling point at a pressure of 40 kPa? (1) propanone (2) ethanoic acid (3) ethanol (4) water

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49. A sample of a gas is at STP. As the pressure decreases and the temperature increases, the volume of the gas (1) decreases (2) increases (3) remains the same

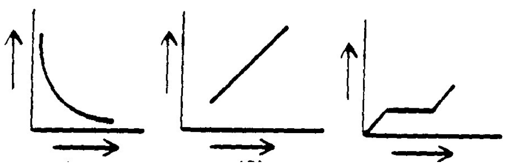
50. A 100. milliliter sample of a gas at a pressure of 50.8 kPa is reduced to 25.4 kPa at constant temperature. What is the new volume of the gas? (1) 50.0 mL (2) 90.0 mL (3) 200. mL (4) 290. mL

51. At constant temperature the pressure on 8.0 liters of a gas is increased from 1 atmosphere to 4 atmospheres. What will be the new volume of the gas? (1) 1.0 ℓ (2) 2.0 ℓ (3) 32 ℓ (4) 4.0 ℓ

52. As the temperature of a sample of gas decreases at constant pressure, the volume of the gas (1) decreases (2) increases (3) remains the same

53. A 100 milliliter sample of a gas is enclosed in cylinder under a pressure of 101.3 kPa. What volume would the gas sample occupy at a pressure of 202.6 kPa, temperature remaining constant? (1) 50 mL (2) 100 mL (3) 200 mL (4) 380 mL

Base your answers to questions 54 and 55 on the graphs shown below.



(1) (2) (3)

Note that questions 54 and 55 have only three choices.

54. Which graph best represents how the volume of a given mass of a gas varies with the Kelvin temperature at constant pressure?

55. Which graph best represents how the volume of a given mass of a gas varies with the pressure on it at constant temperature.

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56. The volume of a sample of hydrogen gas at STP is 1.00 liter. As the temperature decreases, pressure remaining constant, the volume of the sample (1) decreases (2) increases (3) remains the same

57. The pressure on 200. milliliters of a gas at constant temperature is changed from 0.500 atm to 1.00 atm. The new volume of the gas is (1) 100. mL (2) 200. mL (3) 400. mL (4) 600. mL

58. As the pressure on a given sample of a gas increases at constant temperature, the mass of the sample (1) decreases (2) increases (3) remains the same

59. A gas sample is at 10.0 °C. If pressure remains constant, the volume will increase when the temperature is changed to (1) 263 K (2) 283 K (3) 273 K (4) 293 K

60. A gas has a volume of 640 mL at 15 °C and a pressure of 0.537 atm. What is the volume of the gas at STP? (1) 724 mL (2) 362 mL (3) 652 mL (4) 326 mL

61. The volume of a gas at STP is 20 mL. What will the volume be when the pressure and temperature is doubled? (1) 10 mL (2) 20 mL (3) 30 mL (4) 40 mL

62. A cylinder of gas is immersed in a water bath. If the temperature of the water bath is increased and a piston is allowed to move freely so that the pressure on the gas in the cylinder remains at 1 atmosphere, then the gas will (1) increase in pressure (2) increase in volume (3) decrease in pressure (4) decrease in volume

63. If 10 liters of a gas at 273 °C is cooled to 0 °C at constant pressure, the volume of the gas at 0 °C will be (1) 2.5 liters (2) 5 liters (3) 30 liters (4) 40 liters

64. At STP 1.00 mole of oxygen gas would occupy the same volume as (1) 11.2 liters of nitrogen (2) 22.4 liters of chlorine (3) 33.6 liters of hydrogen (4) 44.8 liters of helium

65. A sample of dry hydrogen has a volume of 400 milliliters at STP . If the temperature remains constant and the pressure is changed to 800 millimeters of mercury, then the new volume of the gas will be equal to (1) 400 x 800/760 (2) 400 x 800/273 (3) 400 x 760/800 (4) 400 x 800/800

66. Equal volumes of SO_2(g) and NO(g) at the same temperature and pressure would have the same (1) mass (2) density (3) number of atoms (4) number of molecules

67. As the temperature of a gas increases, the average kinetic energy of the gas particles (1) decreases (2) increases (3) remains the same (4) none of the above

68. The temperature of a 180 mL sample of gas is decreased from 400 K to 200 K , pressure remaining constant. The new volume of the gas is (1) 90 mL (2) 126 mL (3) 273 mL (4) 360 mL

69. The volume of 4.00 grams of helium at 1.00 atm pressure and 20 °C would be (1) less than 11.2 liters (2) 11.2 liters (3) 22.4 liters (4) more than 22.4 liters

70. At standard temperature, the volume occupied by 1.00 mole of gas is 11.2 liters. The pressure exerted on this gas is (1) 1.00 atm (2) 2.00 atm (3) 0.50 atm (4) 1.50 atm

Use the following information to answer the questions71-72 below.

You have two samples of the same gas in the same size container, with the same pressure. The gas in the first container has a kelvin temperature four times that of the gas in the other container.

71. The ratio of the number of moles of gas in the first container compared to that in the second is (1) 1 : 1 (2) 4 : 1 (3) 1 : 4 (4) 2 : 1 (5) 1 : 2

72. The ratio of collisions with the wall in the first container compared to that in the second is (1) 1 : 1 (2) 4 : 1 (3) 1 : 4 (4) 2 : 1 (5) 1 : 2

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73. A gas sample is held at constant pressure The gas occupies 3.62 L of volume when the temperature is 21.6°C. Determine the temperature at which the volume of the gas is 3.45 L. (1) 309 K (2) 281 K (3) 20.6 K (4) 294 K (5) 326 K

74. Gaseous chlorine is held in two separate containers at identical temperature and pressure. The volume of container 1 is 1.30 L and it contains 6.70 mol of the gas. The volume of container 2 is 2.20 L. How many moles of the gas are in container 2? (1) 11.3 mol (2) 19.2 mol (3) 0.427 mol (4) 3.96 mol (5) none of these

75. Two moles of gas A spontaneously convert to 3 mol of products in a container where the temperature and pressure are held constant. The sample originally took up 10.2 L of volume. What is the new volume of the products? (1) 0.189 L (2) 6.73 L (3) 12.3 L (4) 1.15 L (5) 15.3 L

76. *Three 1.00-L flasks at 25°C and 0.954 atm contain the gases CH_4 (flask A), CO_2 (flask B), and C_2H_6 (flask C).* In which flask is there 0.039 mol of gas? (1) flask A (2) flask B (3) flask C (4) all (5) none

77. A gas sample is heated from –20.0°C to 57.0°C and the volume is increased from 2.00 L to 4.50 L. If the initial pressure is 0.125 atm, what is the final pressure? (1) 0.189 atm (2) 0.555 atm (3) 0.0605 atm (4) 0.247 atm (5) none of these

78. Use the ideal gas law to predict the relationship between n and T if pressure and volume are held constant. (1) $n \propto T$ (2) $n \propto 1/T$ (3) n/T = constant (4) $PT = nRV$ (5) $PV/T = R$

79. A 6.35-L sample of carbon monoxide is collected at 55°C and 0.892 atm. What volume will the gas occupy at 1.05 atm and 20°C? (1) 1.96 L (2) 5.46 L (3) 4.82 L (4) 6.10 L (5) none of these

80. Body temperature is about 308 K. On a cold day, what volume of air at 273 K must a person with a lung capacity of 2.00 L breathe in to fill the lungs? (1) 2.26 L (2) 1.77 L (3) 1.13 L (4) 3.54 L (5) none of these

81. Mercury vapor contains Hg atoms. What is the volume of 200. g of mercury vapor at 822 K and 0.500 atm? (1) 135 L (2) 82.2 L (3) 329 L (4) 67.2 L (5) none of these

82. What volume is occupied by 19.6 g of methane (CH4) at 27°C and 1.59 atm? (1) 1.71 L (2) 19.0 L (3) 27.7 L (4) 302 L (5) not enough data to calculate

83. Consider a cylinder fitted with a movable piston. The initial pressure inside the cylinder is P_i and the initial volume is V_i. What is the new pressure in the system when the piston decreases the volume of the cylinder by half? (1) $(1/4)P_i$ (2) $(½)P_i$ (3) $2P_i$ (4) $2V_iP_i$ (5) P_i,

84. A 4.40-g piece of solid CO_2 (dry ice) is allowed to sublime in a balloon. The final volume of the balloon is 1.00 L at 300 K. What is the pressure of the gas? (1) 2.46 atm (2) 246 atm (3) 0.122 atm (4) 122 atm (5) none of these

85. A sample of gas is in a 50.0-mL container at a pressure of 645 torr and a temperature of 25°C. The entire sample is heated to a temperature of 35°C and transferred to a new container whose volume is 65.0 mL. The pressure of the gas in the second container is: (1) 867 torr (2) 694 torr (3) 480. torr (4) 760. torr (5) none of these

86. Given a cylinder of fixed volume filled with 1 mol of argon gas, which of the following is correct? (Assume all gases obey the ideal gas law.) (1) If the temperature of the cylinder is changed from 25°C to 50°C, the pressure inside the cylinder will double. (2) If a second mole of argon is added to the cylinder, the ratio T/P would remain constant. (3) A cylinder of identical volume filled with the same *pressure* of helium must contain more atoms of gas because He has a smaller atomic radius than argon. (4) Two of these. (5) None of these.

87. A 5.10-L sample of chlorine gas is prepared at 15°C and 0.974 atm. Calculate the volume of this sample of chlorine gas at standard conditions of temperature and pressure. (1) 6.41 L (2) 4.71 L (3) 5.89 L (4) 11.4 L (5) 2.97 L

88. A sample of 35.1 g of methane gas (CH_4) has a volume of 5.20 L at a pressure of 2.70 atm. Calculate the temperature. (1) 4.87 K (2) 78.1 K (3) 46.3 K (4) 275 K (5) 129 K

89. Which of the following is *not* a postulate of the kinetic molecular theory? (1) Gas particles have most of their mass concentrated in the nucleus of the atom. (2) The moving particles undergo perfectly elastic collisions with the walls of the container. (3) The forces of attraction and repulsion between the particles are insignificant. (4) The average kinetic energy of the particles is directly proportional to the absolute temperature. (5) All of these are postulates of the kinetic molecular theory.

90. Use the kinetic molecular theory of gases to predict what would happen to a closed sample of a gas whose temperature increased while its volume decreased. (1) Its pressure would decrease. (2) Its pressure would increase. (3) Its pressure would hold constant. (4) The number of moles of the gas would decrease. (5) The average kinetic energy of the molecules of the gas would decrease.

Use the following information to answer the questions 91-92 below.
Three 1.00-L flasks at 25°C and 725 torr contain the gases CH_4 (flask A), CO_2 (flask B), and C_2H_6 (flask C).

91. In which flask is there 0.039 mol of gas? (1) flask A (2) flask B (3) flask C (4) all (5) none

92. In which single flask do the molecules have the greatest mass, the greatest average velocity, *and* the highest kinetic energy? (1) flask A (2) flask B (3) flask C (4) all (5) none

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93. A sample of oxygen gas has a volume of 4.50 L at 27°C and 800.0 torr. How many oxygen molecules does it contain? (1) 1.16×10^{23} (2) 5.8×10^{22} (3) 2.32×10^{24} (4) 1.16×10^{22} (5) none of these

94. Gaseous C_2H_4 reacts with O_2 according to the following equation:
$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$$
What volume of oxygen at STP is needed to react with 1.50 mol of C_2H_4? (1) 4.50 L (2) 33.6 L (3) 101 L (4) 67.2 L (5) Not enough information is given to solve the problem.

95. What volume of carbon dioxide measured at STP will be formed by the reaction of 1.30 mol of oxygen with 9.00×10^{-1} mol of ethyl alcohol CH_3CH_2OH? (1) 8.70 L (2) 19.4 L (3) 28.0 L (4) 40.3 L (5) 91.9 L

96. What volume of $H_2O(g)$ measured at STP is produced by the combustion of 4.00 g of natural gas (CH_4) according to the following equation?
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$
(1) 5.60 L (2) 11.2 L (3) 22.4 L (4) 33.6 L (5) 44.8 L

97. Into a 3.00-liter container at 25°C are placed 1.23 moles of O_2 gas and 3.20 moles of solid C (graphite). If the carbon and oxygen react completely to form CO(g), what will be the final pressure in the container at 25°C? (1) 20.1 atm (2) 26.1 atm (3) 10.2 atm (4) 1.68 atm (5) none of these

98. Calcium hydride combines with water according to the equation:
$$CaH_2(s) + 2H_2O(\ell) \rightarrow 2H_2(g) + Ca(OH)_2(s)$$
Beginning with 84.0 g of CaH_2 and 36.0 g of H_2O, what volume of H_2 will be produced at 273 K and a pressure of 1520 torr? (1) 22.4 L (2) 44.8 L (3) 89.6 L (4) 179 L (5) none of these

99. An excess of sodium hydroxide is treated with 1.1 L of dry hydrogen chloride gas measured at STP. What is the mass of sodium chloride formed? (1) 0.50 g (2) 1.8 g (3) 2.0 g (4) 2.9 g (5) 22 g

Answers

1. 3	21. 3	41. 1	61. 2	81. 5
2. 3	22. 2	42. 3	62. 2	82. 2
3. 4	23. 4	43. 2	63. 2	83. 3
4. 4	24. 3	44. 4	64. 2	84. 1
5. 2	25. 1	45. 3	65. 3	85. 5
6. 1	26. 3	46. 2	66. 4	86. 5
7. 3	27. 1	47. 4	67. 2	87. 2
8. 4	28. 3	48. 2	68. 1	88. 2
9. 1	29. 2	49. 2	69. 4	89. 1
10. 2	30. 1	50. 3	70. 2	90. 2
11. 3	31. 2	51. 2	71. 3	91. 4
12. 4	32. 1	52. 1	72. 1	92. 2
13. 3	33. 4	53. 1	73. 2	93. 1
14. 3	34. 3	54. 2	74. 1	94. 3
15. 1	35. 1	55. 1	75. 5	95. 2
16. 3	36. 4	56. 1	76. 4	96. 2
17. 1	37. 4	57. 1	77. 5	97. 1
18. 2	38. 4	58. 3	78. 2	98. 1
19. 1	39. 2	59. 4	79. 3	99. 4
20. 1	40. 2	60. 4	80. 2	