GRADE 9 SAMPLE QUESTIONS AND SHORT NOTES FOR GRADE 12

STOICHIOMETRY

THESE PROBLEMS ARE PROVIDED TO SEE IF YOU HAVE MASTERED THE CONCEPTS OF THE CHAPTERS COVERED. DO NOT USE YOUR BOOK OR NOTES ON YOUR FIRST ATTEMPT AT THESE PROBLEMS.

1. Which of the following statements does **NOT** correctly describes the following reaction?

N_2 (g) + $3H_2$ (g) → $2NH_3$ (g)

A. 1 mole of N_2 react with 3 moles of H_2 to give 2 moles of NH_3

B. 28g of N_2 react with 6g of H_2 to produce 34g of NH_3

C. 3 liters of N_2 reacts 2 liters of H_2 to produce 2 liters of NH_3

D. 1 molecules of N_2 reacts with 3 molecules of H_2 to gives 2 molecules of NH_3

From a balanced chemical equation, it is possible to determine:

- *The number of moles of each reactant and product and*
- *relative mass of each of the reactants and products*

For example, in the reaction of hydrogen with oxygen to produce water, the equation tells us

$2H_2$ (g)	**+**	**O_2 (g)**	**→**	**$2H_2O$ (l);**
Mole → 2 mole		***1 mole***		***2 mole***
Molecule → 2 molecule		***1 molecule***		***2 molecule***
Mass → 4 g		***32 g***		***2 × 18 g***
		36 g reactant		***36 g product***

STOICHIOMETRY INVOLVING ONLY PURE SUBSTANCES

For all chemical reactions, the balanced chemical equation gives the mole ratios of reactants and products. If we are dealing with pure chemicals, the molar mass allows us to convert the mass of a reactant or product into moles.

1. Mass–Mass Relationships

In mass-mass problems, the mass of one substance is given, and the mass of the second substance is determined from the same reaction. There are two methods for solving such types of problems.

- *Mass-ratio method*
- *Mole-ratio method*

Consider the reaction shown below.

$$Ca_3N_2\,(s) + 6H_2O\,(l) \rightarrow 2NH_3\,(g) + 3Ca(OH)_2\,(s)$$

Mole ratio	1	:	6	:	2	:	3
Molar mass	148.3		18.0		17.0		74.1 (g/mole)

For this reaction, 1 mole of Ca_3N_2 will react with 6 moles of H_2O to produce 2 moles of NH_3 and 3 moles of $Ca(OH)_2$. Therefore, for this reaction 1 mole $Ca_3N_2 \equiv 6$ moles H_2O. Similar equivalences will apply to other pairs of reactants and/or products. For example, 6 moles $H_2O \equiv 2$ moles NH_3.

Mass-ratio method

In this type of stoichiometric calculation, the mass of one substance is determined from the given mass of the other substance.

Example: Calculate the mass of $Ca(OH)_2$ that can be formed from the reaction of 10.0 g of Ca_3N_2 with an excess

Of H_2O. $Ca_3N_2\,(s) + 6H_2O\,(l) \rightarrow 2NH_3\,(g) + 3Ca(OH)_2\,(s)$

Solution: From the balanced equation, 148.3 gm of Ca_3N_2 gives 3x74.1 gm = 222.3 gm

10.0 gm of Ca_3N_2 = X?

X = 10 x 222.3/148.3 = 15 gm

2. Aluminum Oxide is formed when aluminum combines with oxygen in the air. How many grams of Al_2O_3 are formed when 23.6g of Al reacts completely with oxygen?

$4Al + 3O_2 \rightarrow 2Al_2O_3$

A. **<u>44.6 grams</u>** B. 35.6 grams C. 87.6 grams D. 21.6 grams

3. Boron carbonate decomposes into boron oxide and carbon dioxide. How many moles of CO_2 are produced when 5.0 mol of boron carbonate decomposes completely?

$B_2(CO_3)_3 \rightarrow B_2O_3 + 3CO_2$

A. **<u>15 mol</u>** B. 1.67 mol C. 5 mol D. 8 mol

The mole- ratio method

The mole ratio is the ratio between the numbers of moles of any two substances in a given reaction. In this method, the given mass is converted into moles, and the number of moles for the required substance is calculated. If needed, convert the obtained moles back to mass.

Example: How many moles of H_2O are required to produce 4.5 moles of HNO_3 according to the following

reaction: **$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$**

Solution: From the balanced equation, 2 moles of HNO_3 are produced from 1 mole of H_2O

4.5 moles of HNO_3 are produced from x mole of H_2O

X = 4.5 x ½ = 2.25 moles HNO_3

4. Given 2.30 grams of Fe, how many moles of $FeCl_3$ can be produced?

$2Fe + 3Cl_2 \rightarrow 2FeCl_3$

A. **<u>0.04 moles</u>** B. 0.08 moles C. 0.02 moles D. 2.3 moles

5. How many liters of fluorine gas can be produced when 0.67 L of HF reacts with excess O_2 at STP?

$4HF + O_2 \rightarrow 2F_2 + 2H_2O$

A. 0.67 L B. 2.68 L **C. <u>0.335 L</u>** D. 1.34 L

2. Volume- Volume relation ship

Avogadro's hypothesis states that equal volumes of all gases at the same temperature and pressure contain the same number of gas particles. Further, one mole of any gas at standard temperature and pressure **(0^oC and 1atm)** occupies a volume of **22.4L**. These characteristics make stoichiometry problems involving gases at STP very straightforward. Consider the reaction of nitrogen and oxygen gases to form nitrogen dioxide:

N_2 (g)	**+**	**$2O_2$ (g)**	**→**	**$2NO_2$ (g)**
1 molecule		**2 molecules**		**2 molecules**
1 mol		**2 mol**		**2 mol**
1 Volume		**2 Volumes**		**2 Volumes**

Example: The combustion of propane gas produces carbon dioxide and water vapor.

C_3H_8 (g) + $5O_2$ (g) → $3CO_2$ (g) + $4H_2O$ (g)

a. What volume of oxygen is required to completely combust 0.650L of propane?
b. What volume of carbon dioxide is produced in the reaction?

Known

- Given: 0.650LC_3H_8
- 1 volume C_3H_8 = 5 C_3H_8 = 5 volumes O_2
- 1 volume C_3H_8 = 3 C_3H_8 = 3 volumes CO_2

Solution:

a. 1 L C_3H_8 = 5 L O_2 b. **1.95 L CO_2**

0.650 L C_3H_8 = X

X = 3.25 L O_2

Example: What volume of oxygen will react with carbon monoxide to produce 20 litres of carbon dioxide at STP? $2CO + O_2 \rightarrow 2CO_2$

Solution: 1 mol of any gas at STP occupies a volume of 22.4 L

22.4 L O_2 = 2 x 22.4 L CO_2

X L of O_2 = 20 L CO_2

X= 10 L O_2

Note that total volume is not necessarily conserved in a reaction because moles are not necessarily conserved. In this reaction, 6 total volumes of reactants become 7 total volumes of products.

3. Mass–Volume Relationships

In mass-volume problems, either the mass of one substance is given and the volume of the other is required or the volume of one substance is given and the mass of the other one is required

Example: How many grams of calcium carbonate are decomposed to produce 11.2 L of carbon dioxide at STP?

$CaCO_3 \rightarrow CaO + CO_2$

Solution: 1 mol $CaCO_3$ (100 g) = 1 mol CO_2 (22.4 L)

X g $CaCO_3$ = 11.2 L CO_2

X = **50 g $CaCO_3$**

6. How many liters of O_2 at STP will react with 8.7 grams of C_2H_4 to form CO_2 and H_2O?

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

A. **<u>20.16 L</u>** B. 2.32 L C. 22.4 L D. 6.54 L

Solution: $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

1 C_2H_4 = 3 O_2

1 mol = 3 mol

1 mol = 3 x 22.4 L

8.7 gm/28 g/mol = ?

= 20.16 **L**

DETERMINING LIMITING AND EXCESS REAGENTS

Limiting Reagent: The limiting reagent in a chemical reaction is the reactant that will be consumed completely. Once there is no more of that reactant, the reaction cannot proceed. Therefor it limits the reaction from continuing. The limiting reagent gives the smallest yield of product calculated from the reagents (reactants) available. This smallest yield of product is called the theoretical yield.

To find the limiting reagent and theoretical yield, carry out the following procedure:

i. Find the moles of each reactant present.
ii. Calculate the moles of a product formed from each mole of reactant.
iii. Identify the reactant giving the smaller number of moles of product. This reactant is the Limiting Reagent:
iv. Calculate the grams of product produced by the Limiting Reagent. This is the theoretical yield.

THEORETICAL YIELD: The theoretical yield is the amount of the product in g formed from the limiting reagent. From the moles of limiting reagent available, calculate the grams of product that is theoretically possible

ACTUAL YIELD: The actual yield is the amount of the product in g actually formed in the laboratory

PERCENT YIELD: The percent yield is the percent of the product formed based upon the theoretical yield

$$\frac{\text{actual yield in g}}{\text{theoretical yield in g}} \times 100\ \% = \text{Percent Yield}$$

Excess Reagent: The excess reagent is the reactant that could keep reacting if the other had not been consumed.

Example: If we have 14.8g of propane, and 34.4g of oxygen, determine

a. The limiting reagent
b. The number of moles carbon dioxide produced
c. Mass of water produced
d. Mass of excess reagent

Solution: First, we need a chemical equation and moles of each component.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

No of moles of $C_3H_8 = m/M = 14.8/44 = 0.336$ mol

No of moles of $O_2 = m/M = 34.4/32 = 1.075$ mol

Now that we have the amounts of propane and oxygen, we can find out how much carbon dioxide will be produced.

$$.336\ mol C_3H_8 * \frac{3\ mol\ CO_2}{1\ mol\ C_3H_8} = 1.01\ mol\ CO_2$$

$$1.075\ mol\ O_2 * \frac{3\ mol\ CO_2}{5\ mol\ O_2} = .645\ mol\ CO_2$$

This means:

- Oxygen is the limiting reactant
- 0.645 moles of carbon dioxide will be formed.
- We can also figure out how many moles of water are produced, and therefore how much mass.

$$1.075\ mol\ O_2 * \frac{4\ mol\ H_2O}{5\ mol\ O_2} * \frac{18.02g\ H_2O}{1\ mol\ H_2O} = 15.5\ g\ H_2O$$

- Finally, we can find the excess needed.

$$1.075\ mol\ O_2 * \frac{1\ C_3H_8}{5\ O_2} = .215\ mol\ C_3H_8\ needed$$

$$.336\ molC_3H_8\ to\ start - .215\ mol\ C_3H_8\ needed = .121\ molC_3H_8\ in\ excess$$

$$.121\ molC_3H_8 * \frac{44.1g\ C_3H_8}{1\ mol\ C_3H_8} = 5.34\ g\ C_3H_8\ in\ excess$$

7. Which statement is true if 18 mol CO and 18 mol Fe_2O_3 are allowed to react? HINT: Determine the limiting reactant first, then convert the limiting reactant to moles of CO_2 and moles of Fe to see which is correct.

$3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$

A. The limiting reactant is CO and 12 mol of CO2 will be formed
B. The limiting reactant is Fe_2O_3 and 8 mol Fe will be formed
C. **The limiting reactant is CO and 12 mol of Fe will be formed**
D. The limiting reactant is Fe_2O_3 and 8 mol CO_2 will be formed

8. What is the limiting reactant if 20.0 moles of O_2 react with 30.0 moles of H_2 according to the following reaction? **$2H_2 + O_2 \rightarrow 2H_2O$**

A. **H_2** B. O_2 C. Both A and B. D. H_2O

9. For the reaction equation, **$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$,** 21.0 g of nitrogen gas will react with an excess of hydrogen gas to give an actual yield of 3.85 g. What is the percent yield for this reaction? **Ans. 15.1%**

10. When 25.0 g $Mg(OH)_2$ and 25.0 g HCl are mixed and reacted, the amount of unreacted material will be

$Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

A. 9.34 g HCl B. 2.96 g HCl C. **5.00 g $Mg(OH)_2$** D. 15.0 g $Mg(OH)_2$

11. What does percent yield indicate?

A. The amount of product we should get
B. The amount of product we actually got
C. **The efficiency of the lab**
D. nothing

12. **$2Fe_2O_3 + C \rightarrow Fe + 3CO_2$**, you add 28 grams of carbon. You find the actual yield to be 181.2 grams of CO_2. What is the percent yield of CO_2? (Hint: calculate theoretical yield of CO_2 first)

A. **15.8%** B. 209.2% C. 6435% D. 15.5%

13. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$, 15 grams of HCl should theoretically produce 0.42 grams of H_2. The reaction actually produced 0.15 grams of H_2. What is the percent yield of H_2?

A. 2.8% B. 280% C. 1% D. **36%**

RELATIONSHIP BETWEEN T^0, VOLUME, AND PRESSURE.-Review

- Boyle's law: P & V
  As the pressure increases the volume decreases in the same proportion
- Charles's law: T^0 & V
  As the temperature (Kelvin) is increased the volume is increased proportionally
- Gay-Lussac's Law: T^0 & P
  When temperature (K) increases pressure increases proportionally
- Avogadro's Law: Volume and Amount (in moles, n)
  When the amount (moles, n) increases volume increases proportionally.
- COMBINATION OF THE GAS LAWS-Review: P, V, and T^0 varying.
  Assume that the mass is constant.

14. Boyle's law states that for a fixed amount of gas at a constant
    A. Pressure, the volume increases as the temperature decreases
    B. Temperature, the volume increases as the pressure increases
    C. Temperature, the volume decreases as the pressure increases
    D. Pressure, the volume decreases as the temperature increases
15. Which of the following element contains the greatest number of atoms?
    A. 4 g He B. 46 g Na C. 0.4 g Ca D. 12 g He

    Solution: Number of atoms present in W g of a substance = **W/M × Na.** Here, Na represents Avogadro's number. M represents the atomic mass of substance.
    - Number of atoms in 4 g He = 4/4 × NA = NA
    - Number of atoms in 46 g of Na = 46/23xNA = 2NA
    - Number of atoms in 0.40 g of Ca = 0.4/40NA = 0.01NA
    - Number of atoms in 12 g of He = 12/4NA = 3NA

      Hence, 12 g of helium has the maximum number of atom
16. In the reaction 2A + 4B → 3C + 4D, when 5 moles of A react with 6 moles of B, then the amount of C formed is: A. 3 mol B. 4 mol C. 5.5 mol D. **4.5 mol**

    Solution: Here, 5 mole of A need 10 mole of B to react, thus B is a limiting agent. 3 moles of A can react with 6 moles of B, thus the no. of moles of C formed **= 3/2 × 3 = 4.5 mol**
17. A sample of hydrogen has a volume of 25 L under a pressure of 5 atm. What will the pressure of this gas be if the volume were decreased to 5 L?
    A. **25 atm** B. 15 atm C. 10 atm D. 5 atm E. 1 atm

    Solution: We know that pressure of a gas is inversely proportional to its volume (Boyle's Law). So, one of the gas equations can be written as- **$P_1V_1=P_2V_2$**
18. At constant pressure, what happens to the volume of a gas at 298 K, when the temperature doubles to 596 K?
    A. It is doubled B. It is halved C. It remains unchanged D. It is quadrupled.
19. 1000 mL of a gas is cooled from 500 K to 250 K. What is its final volume?
    A. 500 mL B. 1000 mL C. 250 mL D. 2000 mL E. 750 mL

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

$$\frac{1000}{V_2} = \frac{500}{250}$$

$$V_2 = \frac{1000 \times 250}{500} = 500\text{mL}$$

20. Assuming pressure and temperature are held constant, then what happens to the volume of a non-rigid container when the number of molecules in the container is doubled?
    A. **The volume doubles**
    B. The volume stays the same
    C. There is not enough information given to determine this.
    D. It decreases to half its original volume.
    E. It increases by a factor of four

    The ideal gas equation is: **PV=nRT.** At constant pressure and temperature, V**∝ n.** Thus, volume of a gas, at constant pressure and temperature is directly proportional to the number of moles of gas. When number of molecules in the container is doubled, the number of moles in the container is doubled and the volume of the non-rigid container is also doubled.

21. A sample of oxygen occupies 47.2 liters under a pressure of 1240 torr at 25°C. What volume would it occupy at 25oC if the pressure were decreased to 730 torr?

A. 27.8 L B. 29.3 L C. 32.3 L D. 47.8 L E. **80.2 L**

22. Which one of the following statements is not consistent with the kinetic-molecular theory of gases?

A. Individual gas molecules are relatively far apart.
B. The actual volume of the gas molecules themselves is very small compared to the volume occupied by the gas at ordinary temperatures and pressures.
C. The average kinetic energies of different gases are different at the same temperature.
D. There is no net gain or loss of the total kinetic (translational) energy in collisions between gas molecules.
E. The theory explains most of the observed behavior of gases at ordinary temperatures and pressures

Graham's Law of Diffusion

Diffusion: Spreading of gas molecules throughout a container until evenly distributed

Effusion: Passing of gas molecules through a tiny opening in a container

Graham's law of diffusion states that at constant temperature and pressure, the rate of diffusion of a gas, r, is inversely proportional to the square root of its density, d, or molar mass, M.

Larger mass ⇒ smaller velocity

Mathematically it can be expressed as:

$$r \propto \sqrt{\frac{1}{d}} \quad \text{or} \quad r \propto \sqrt{\frac{1}{M}};$$

where r is the rate of diffusion, d is the density and M is the molecular mass of the gas.

For two gases (Gas 1 *and* Gas 2), their rates of diffusion can be given as:

$$r_1 \propto \sqrt{\frac{1}{d_1}} \quad or \quad r_1 \propto \sqrt{\frac{1}{M_1}}$$

and

$$r_2 \propto \sqrt{\frac{1}{d_2}} \quad or \quad r_2 \propto \sqrt{\frac{1}{M_2}}$$

Rearranging these relationships gives the following expression

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}} \quad or \quad \frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}};$$

Example: Which gas will diffuse faster, ammonia or carbon dioxide? What is the relative rate of diffusion?

$$\frac{r_{NH_3}}{r_{CO_2}} = \sqrt{\frac{M_{CO_2}}{M_{NH_3}}} = \sqrt{\frac{44}{17}} = 1.6$$

This means rate of diffusion of NH_3 is 1.6 times that of CO_2.

Example: The rate of diffusion of methane (CH_4) is twice that of an unknown gas. What is the molecular mass of the gas?

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} \Rightarrow \frac{r_{CH_4}}{r_x} = \sqrt{\frac{M_x}{M_{CH_4}}}$$

$$\frac{2r_X}{r_X} = \sqrt{\frac{M_X}{16}} \Rightarrow M_X = 64$$

Therefore, the molecular mass of the unknown gas is 64

23. Organize the following gasses in order of their rates of diffusion, from slowest to fastest

Oxygen, O_2 ammonia, NH_3 hydrogen, H_2 and carbon dioxide, CO_2

A. Hydrogen, oxygen, carbon dioxide, ammonia
B. Hydrogen, ammonia, oxygen, carbon dioxide
C. Carbon dioxide, oxygen, ammonia, hydrogen
D. Oxygen, hydrogen, carbon dioxide, ammonia
E. Hydrogen, oxygen, ammonia, carbon dioxide

24. If 3.25 mol of Ar occupies 100. L at a particular temp and pressure, what volume does 14.15 mol of Ar occupy under same condition?

A. **435 L** B. 225 L C. 100 L D. 522 L

Step 1: List the given values.

$V_1 = 100.\ \text{L}$

$n_1 = 3.25\ \text{mol}$

$n_2 = 14.15\ \text{mol}$

Step 2: Calculate the final volume of the gas by using Avogadro's law.

$$V_2 = \frac{V_1 n_2}{n_1}$$

$$= \frac{(100.\ \text{L})(14.15\ \text{mol})}{3.25\ \text{mol}}$$

$$= \boxed{435\ \text{L}}$$

Hence, the volume of 14.15 mol of Ar is **435 L**.

25. How many molecules are there in a 110 L sample of gas at STP?

A. 8×10^{23} molecules B. 8×10^{24} molecules C. **3×10^{24} molecules** D. 3×10^{23} molecules

26. An unknown gas effuses 1.73 times faster than krypton. What is the molar mass of the gas?

A. **28.0 g/mol** B. 48.4 g/mol C. 110 g/mol D. 251 g/mol

27. Which of the following is an example of displacement reaction?

A. $4\ Na + O_2 \rightarrow 2Na_2O$ C. $2Cu + O_2 \rightarrow 2CuO$

B. **$Mg + 2HCl \rightarrow MgCl_2 + H_2$** D. $N_2 + 3H_2 \rightarrow 2NH_3$

28. Which of the following is true of a balanced equation?

A. The number of atoms per molecule remains the same

B. The kinds of atoms remain the same

C. The total number of molecules remains the same

D. The number of atoms of each element remains the same

29. Which of the following reactions is incorrectly classified?

A. $Mg\ (s) + 2HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$; (single-replacement)

B. $PbO\ (s) + C\ (s) \rightarrow Pb\ (s) + CO\ (g)$; (double-replacement)

C. $CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)2\ (aq)$; (synthesis)

D. $Pb(NO3)_2\ (aq) + 2LiCl\ (aq) \rightarrow 2LiNO_3\ (aq) + PbCl_2\ (s)$; (double-replacement)