

The mole

- A mole is a collection that contains
- the same numbers of particles as there are carbon atoms in 12.0 g of carbon.
- 6.02×10^{23} atoms of an element { Avogadro's number }

1 mole element

Number of Atoms

$$1 \text{ mole C} = 6.02 \times 10^{23} \text{ C atoms}$$

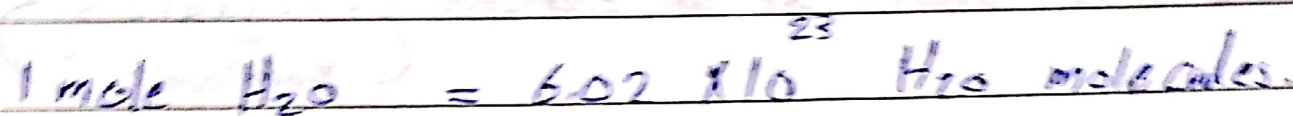
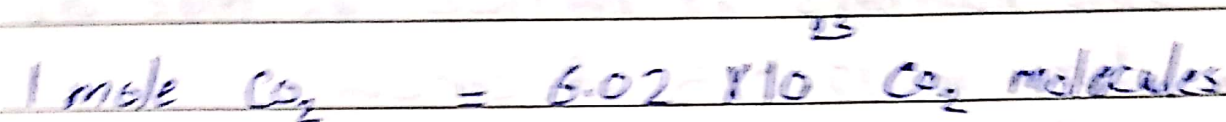
$$1 \text{ mole Na} = 6.02 \times 10^{23} \text{ Na atoms}$$

$$1 \text{ mole Au} = 6.02 \times 10^{23} \text{ Au atoms}$$

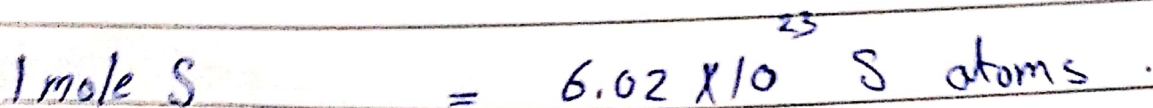
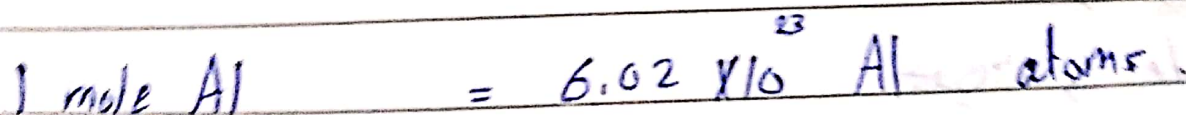
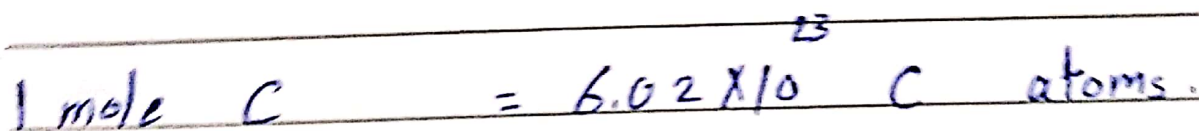
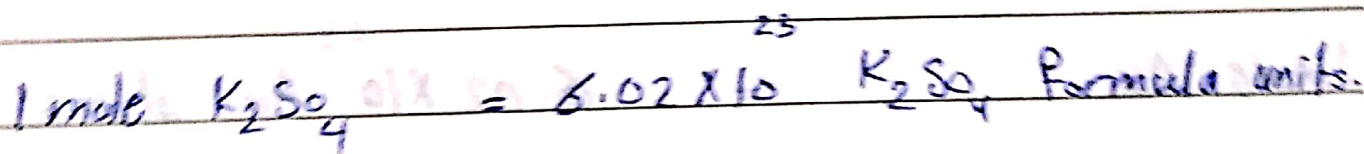
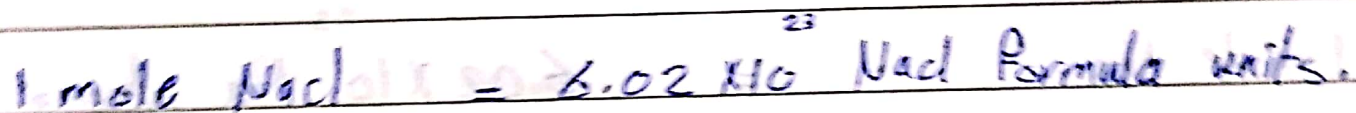
atoms → ذرات

molecule → جزيئات

A mole of a covalent compound has "Avogadro's" number of molecules.



of an ionic compound contains Avogadro's number of formula units. -



$$1 \text{ mole H}_2\text{O} = 6.02 \times 10^{23} \text{ H}_2\text{O molecules}$$

$$1 \text{ mole CCl}_4 = 6.02 \times 10^{23} \text{ CCl}_4 \text{ molecules}$$

$$1 \text{ mole} = 6.02 \times 10^{23} \text{ particles}$$

Conversion Factors :

$$\frac{6.02 \times 10^{23} \text{ Particles}}{1 \text{ mole}} \quad \text{and} \quad \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ Particles}}$$

□ How many Cu atoms are 0.50 mole Cu?

$$* \quad 0.50 \text{ mole Cu} \times \frac{6.02 \times 10^{23} \text{ Cu atoms}}{1 \text{ mole Cu}}$$

$$= 3.01 \times 10^{23} \text{ Cu atoms}$$

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[2] How many moles of CO_2 are in 2.50×10^{24} molecules?

$$\begin{aligned} & \times \quad 2.50 \times 10^{24} \text{ molecules } \text{CO}_2 \times \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ molecules } \text{CO}_2} \\ & = 4.15 \text{ mole } \text{CO}_2 \end{aligned}$$

[3] The number of atoms in 2.0 mole Al is

(a) 2.0 Al atoms

(b) 3.0×10^{23} Al atoms,

(c) 1.2×10^{24} Al atoms,

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[4] The number of moles of S in 1.8×10^{48} atom S is

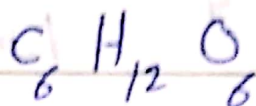
(a) 1.0 mole S atoms,

(b) 3.0 mole S atoms,

(c) $1/1 \times 10^{48}$ mole S atoms,

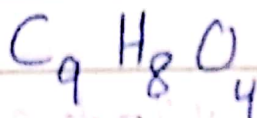
The subscripts in a formula show

- the relationship of atoms in the formula
- the moles of each element in 1 mole of compound



In 1 molecule : 6 atoms C 12 atoms H 6 atoms O

In 1 mole : 6 mole C 12 mole H 6 mole O



9 mole C	8 mole H	4 mole O
1 mole $\text{C}_9\text{H}_8\text{O}_4$	1 mole $\text{C}_9\text{H}_8\text{O}_4$	1 mole $\text{C}_9\text{H}_8\text{O}_4$

Q How many mole O are in 0.150 mole aspirin $C_9H_8O_4$?

$$* 0.150 \text{ mole } C_9H_8O_4 \times \frac{4 \text{ mole O}}{1 \text{ mole } C_9H_8O_4}$$

$$= 0.600 \text{ mole O}$$

Q How many atom O are in 0.150 mole aspirin $C_9H_8O_4$?

$$* 0.150 \text{ mole } C_9H_8O_4 \times \frac{4 \text{ mole O}}{1 \text{ mole } C_9H_8O_4} \times \frac{6.02 \times 10^{23} \text{ O atoms}}{1 \text{ mole O}}$$

$$= 3.61 \times 10^{23} \text{ O atoms}$$

Molar Mass الكتلة المولية

* is the mass of one mole of an element or compound.

* is the atomic mass expressed in grams.

Q1 Give the molar mass for each :-

① 1 mole K atoms = 39.1 g

② 1 mole Sn atoms = 118.7 g

Q2 calculate the molar mass of CaCl_2 .

CaCl_2		molar mass
	Ca	40.1 g
* 2 x 35.5 = 71.0 g		
	Cl	35.5 g
* 71.0 + 40.1 = 111.1		

Q1 calculate the molar mass K_3PO_4 ?

$$* 4 \times 16.0 + 1 \times 31.0 + 3 \times 39.1 \quad \begin{array}{l} \text{O} \\ \text{P} \\ \text{K} \end{array} \quad \begin{array}{l} \text{molar mass} \\ 16.0 \\ 31.0 \\ 39.1 \end{array}$$

$$* 64.0 + 31.0 + 117.3 \quad \text{P} \quad 31.0$$

$$= 212.3 \text{ g} \quad \text{O} : 4 \times 16.0$$

Q1 what is the molar mass of each of the following:

(A) K_2O

$$* 1 \times 16.0 + 2 \times 39.1$$

$$= 94.2 \text{ g}$$

(B) $Al(OH)_3$

$$* 1 \times 27.0 + 3 \times 16.0 + 3 \times 1.01$$

$$= 78.0 \text{ g}$$

	molar mass
K	39.1
O	16.0
Al	27.0
H	1.01

Q1 Prozac, $C_{17}H_{18}F_3NO$ is an antidepressant that inhibits the uptake of serotonin by the brain.

what is the molar mass of prozac?

1) 40.1 g/mole

2) 262 g/mole

3) 309 g/mole

Molar mass conversion factors

— are written from molar mass.

— relate grams and moles of an element or compound.

□ write molar mass factors for methane, CH_4 used in gas stoves and gas heaters.

$$1 \text{ mol } CH_4 = 16.0 \text{ g}$$

conversion factors

$$\frac{16.0 \text{ g } CH_4}{1 \text{ mole } CH_4}$$

and

$$\frac{1 \text{ mole } CH_4}{16.0 \text{ g } CH_4}$$

[2] Acetic acid $C_2H_4O_2$ gives the sour taste to vinegar write two molar mass factors for acetic.
"molar mass"

$$\rightarrow 24.0 + 4.04 + 32.0 = 60.0 \text{ g/mole}$$

1 mole of acetic acid = 60.0 g acetic acid

1 mole acetic acid and 60.0 g acetic acid
60.0 g acetic acid 1 mole acetic acid

* molar mass factors are used to convert between the grams of a substance and the number of moles.

Grams $\xleftarrow{\text{Molar mass factor}}$ Moles

☒ Aluminum is often used to build light weight bicycle frames. How many grams of Al are in 3.00 mole Al?

* Molar mass equality : 1 mole Al = 27.0 g Al
setup with molar mass as a factor:

$$3.00 \text{ mole Al} \times \frac{27.0 \text{ g Al}}{1 \text{ mole Al}} = 81.0 \text{ g Al}$$

☒ Allyl sulfide $C_6H_{10}S$ is a compound that has the odor of garlic. How many moles of $C_6H_{10}S$ are in 225 g?

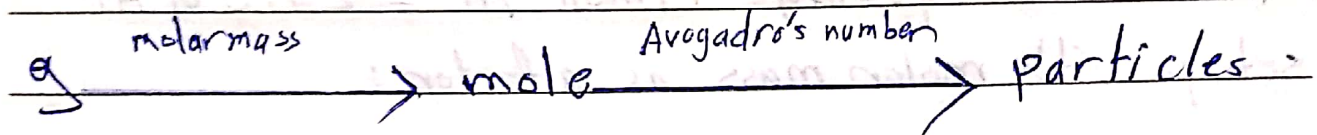
* (molar mass) $6 \times 12.0 + 10 \times 1.01 + 1 \times 32.1$
 $= 114.2 \text{ g/mole}$

$$225 \text{ g } C_6H_{10}S \times \frac{1 \text{ mole } C_6H_{10}S}{114.2 \text{ g } C_6H_{10}S}$$

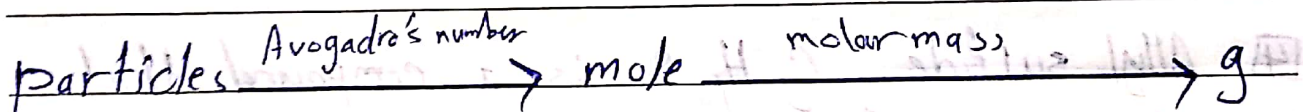
$$= 1.97 \text{ mole } C_6H_{10}S$$

A molar mass factor and Avogadro's number

* grams to particles



* particles to grams



Q1 How many H_2O molecules are in 24.0 g H_2O ?

① 4.52×10^{23}

② 1.44×10^{25}

③ 8.03×10^{23}

$$24.0 \text{ g H}_2\text{O} \times \frac{1 \text{ mole H}_2\text{O}}{18.0 \text{ g H}_2\text{O}} \times \frac{6.02 \times 10^{23}}{1 \text{ mole H}_2\text{O}}$$

$= 8.03 \times 10^{23} \text{ H}_2\text{O molecules}$

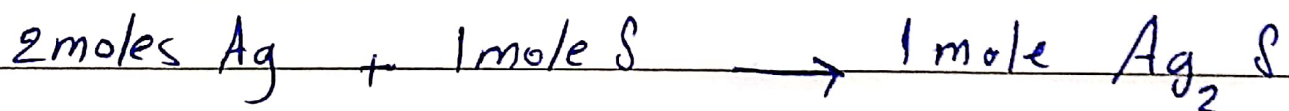
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Q1 If the odor of $C_6H_{10}S$ can be detected from 2×10^{-13} in one liter how many molecules of $C_6H_{10}S$ are present.

$$* 2 \times 10^{-13} \text{ g} \times \frac{1 \text{ mole}}{114.2 \text{ g}} \times \frac{6.02 \times 10^{23} \text{ molecule}}{1 \text{ mole}}$$

$$= 1 \times 10^9 \text{ molecules } C_6H_{10}S$$

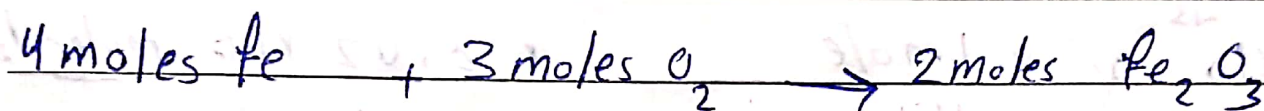
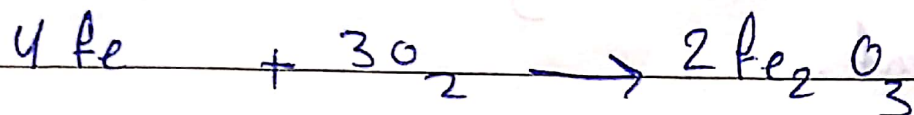
Conservation of Mass



$$2(107.9) + 1(32.1) \text{ g} = 247.9 \text{ g}$$

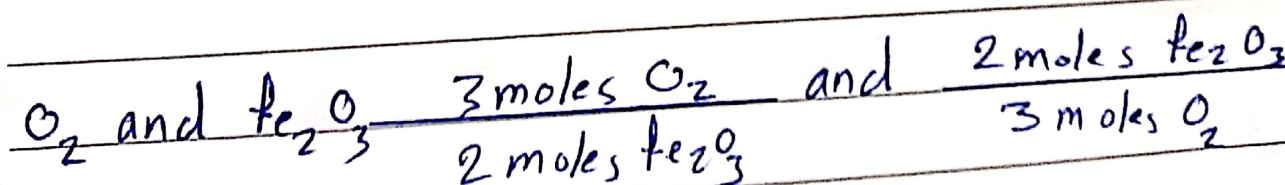
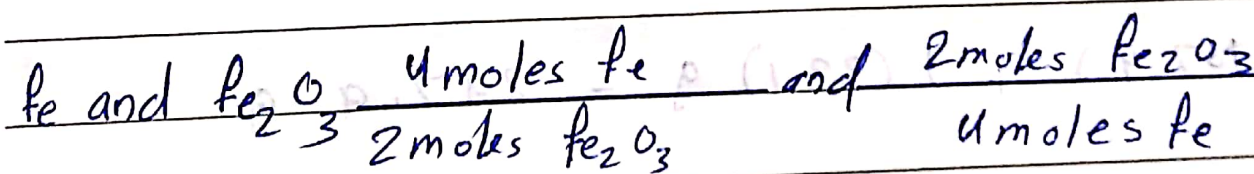
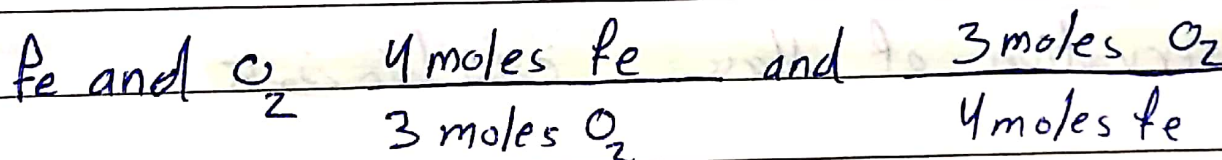
$$247.9 \text{ g reactants} = 247.9 \text{ g product}$$

Q1] Consider the following equation:

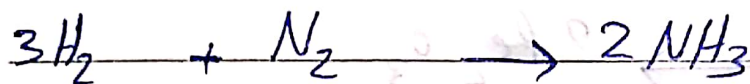


A mole - mole factor is a ratio of the moles for any two substances in an equation

مثال



Consider the following equation :



A. A mole - mole factor for H_2 and N_2 is

1. $\frac{3 \text{ moles } \text{N}_2}{1 \text{ mole } \text{H}_2}$

2. $\frac{1 \text{ mole } \text{N}_2}{3 \text{ moles } \text{H}_2}$

3. $\frac{1 \text{ mole } \text{N}_2}{2 \text{ moles } \text{H}_2}$

B. A mole - mole factor for NH_3 and H_2 is

1. $\frac{1 \text{ mole } \text{H}_2}{2 \text{ mole } \text{NH}_3}$

2. $\frac{2 \text{ mole } \text{NH}_3}{3 \text{ moles } \text{H}_2}$

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Q1 How many moles of Fe_2O_3 can form 6.0 mole?



A. write a mole - mole factor to determine the moles of Fe_2O_3

$$* 6.0 \text{ mole } \text{O}_2 \times \frac{2 \text{ mole } \text{Fe}_2\text{O}_3}{3 \text{ mole } \text{O}_2}$$

$$= 4.0 \text{ mole } \text{Fe}_2\text{O}_3$$

Suppose we want to determine the mass (g) of NH_3 that can form from 2.50 moles N_2 .



The plan needed would be

moles N_2 $\rightarrow$ moles NH_3 $\rightarrow$ grams NH_3

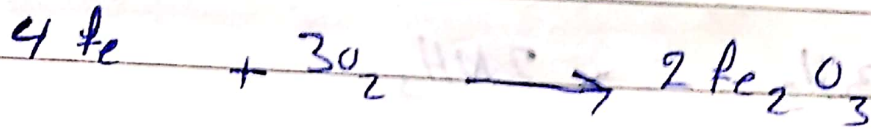
The factor needed would be 1

mole factor NH_3 / N_2 and the molar mass NH_3

$$2.50 \text{ mole } \text{N}_2 \times \frac{2 \text{ moles } \text{NH}_3}{1 \text{ mole } \text{N}_2} \times \frac{17.04 \text{ g } \text{NH}_3}{1 \text{ mole } \text{NH}_3}$$

$$= 85.0 \text{ g } \text{NH}_3$$

Q1 How many grams of O_2 are needed to produce 0.400 mole Fe_2O_3 in the following reaction?

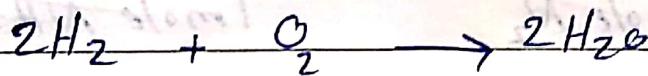


1) 38.4 g O_2

2) 19.2 g O_2 $\rightarrow 0.400 \text{ mole } Fe_2O_3 \times \frac{3 \text{ mole } O_2}{2 \text{ mole } Fe_2O_3} \times \frac{32.0 \text{ g } O_2}{1 \text{ mole } O_2}$

3) 1.90 g O_2 $= 19.2 \text{ g } O_2$

Q1 The reaction between H_2 and O_2 produces 13.1 g water. How many grams of O_2 reacted?



The plan and factors would be

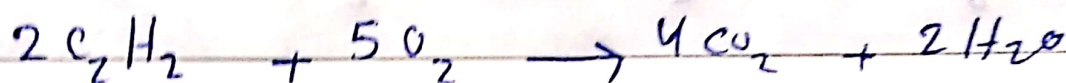
g H_2O $\rightarrow$ mole H_2O $\rightarrow$ mole O_2 $\rightarrow$ g O_2

$$13.1 \text{ g } H_2O \times \frac{1 \text{ mole } H_2O}{18.0 \text{ g } H_2O} \times \frac{1 \text{ mole } O_2}{2 \text{ mole } H_2O} \times \frac{32.0 \text{ g } O_2}{1 \text{ mole } O_2}$$

$$= 11.6 \text{ g } O_2$$

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Q1 Acetylene gas C_2H_2 burns in the oxyacetylene torch for welding. How many grams of C_2H_2 are burned if the reaction produces 75.0 g CO_2 ?



1) 88.6 g C_2H_2

2) 44.3 g C_2H_2

$$\begin{aligned} 3) 22.2 \text{ g } C_2H_2 &\rightarrow 75.0 \text{ g } CO_2 \times \frac{1 \text{ mole } CO_2}{44.0 \text{ g } CO_2} \times \frac{2 \text{ mole } C_2H_2}{4 \text{ mole } CO_2} \times \frac{26.0 \text{ g } C_2H_2}{1 \text{ mole } C_2H_2} \\ &= 22.2 \text{ g } C_2H_2 \end{aligned}$$

Q1. How many grams H_2O are produced when 35.8 g C_3H_8 react by the following equation



1) 14.6 g H_2O

2) 58.4 g H_2O $\rightarrow 35.8 \text{ g } C_3H_8 \times \frac{1 \text{ mole } C_3H_8}{44.1 \text{ g } C_3H_8} \times \frac{4 \text{ mole } H_2O}{1 \text{ mole } C_3H_8} \times \frac{18.0}{1 \text{ mole}}$

3) 117 g H_2O

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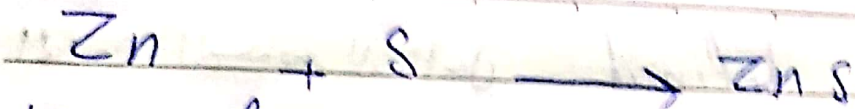
Limiting reagent defined

Limiting reagent : reagent (reactant) that is completely consumed in a reaction.

Limiting reagent : reagent (reactant) that limits amount of product.

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12 g of Zn are mixed with 6.5 g S

① Determine the L.R

$$* 12.0 \text{ g Zn} \times \frac{1 \text{ mole Zn}}{65.4 \text{ g Zn}} = 0.183 \text{ moles Zn}$$

$$* 6.5 \text{ g S} \times \frac{1 \text{ mole S}}{32.1 \text{ g S}} = 0.202 \text{ moles S}$$

Zn (L.R)

② How many grams of ZnS produced

$$* 0.183 \text{ mole Zn} \times \frac{1 \text{ mole ZnS}}{1 \text{ mole Zn}} \times \frac{97.5 \text{ g ZnS}}{1 \text{ mole ZnS}}$$

$$= 17.8 \text{ ZnS}$$

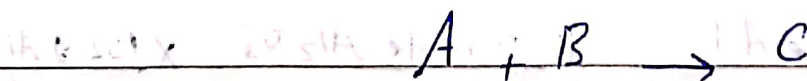
③ How many grams of which reactant will remain unreacted.

$$* 0.202 - 0.183 = 0.019 \text{ mole S left}$$

$$0.019 \text{ mole S} \times \frac{32.1 \text{ g S}}{1 \text{ mole S}} = 0.61 \text{ g S}$$

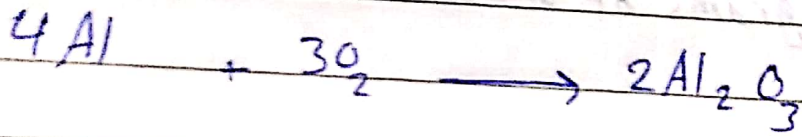
④ If you obtain 8.9 g of ZnS from your reaction what is the percent yields.

$$* \text{percent yields} = \frac{8.9}{17.8} \times 100\% = 50\%$$



A is LR $\rightarrow$ calculate amount of C

B is LR $\rightarrow$ calculate amount of C

Ex

5 g of Al are mixed with 5 g O_2

How many grams of Al_2O_3 are produced

1) 9.44 g

2) 10.6 g

3) 11.6 g

4) 15.6 g

* Al is LR

$$5 \text{ g Al} \times \frac{1 \text{ mole Al}}{27 \text{ g Al}} \times \frac{2 \text{ mole Al}_2\text{O}_3}{4 \text{ mole Al}} \times \frac{102 \text{ g Al}_2\text{O}_3}{1 \text{ mole Al}_2\text{O}_3} = 9.44 \text{ g Al}_2\text{O}_3 \quad \checkmark$$

* O_2 is LR

$$5 \text{ g O}_2 \times \frac{1 \text{ mole O}_2}{32 \text{ g O}_2} \times \frac{2 \text{ mole Al}_2\text{O}_3}{3 \text{ mole O}_2} \times \frac{102 \text{ g Al}_2\text{O}_3}{1 \text{ mole Al}_2\text{O}_3} = 10.6 \text{ g Al}_2\text{O}_3$$

* Al_2O_3 is LR

Q] How many grams of AgBr can be produced when 50.0 g of MgBr_2 is mixed with 100.0 g of AgNO_3 as shown below!



* MgBr_2 is LR

$$50.0 \text{ g } \text{MgBr}_2 \times \frac{1 \text{ mole } \text{MgBr}_2}{184.1 \text{ g } \text{MgBr}_2} \times \frac{2 \text{ mole } \text{AgBr}}{1 \text{ mole } \text{MgBr}_2} \times \frac{187.8 \text{ g } \text{AgBr}}{1 \text{ mole } \text{AgBr}}$$

$$= 102 \text{ g } \text{AgBr}$$

* AgNO_3 is LR

$$100 \text{ g } \text{AgNO}_3 \times \frac{1 \text{ mole } \text{AgNO}_3}{169.9 \text{ g } \text{AgNO}_3} \times \frac{2 \text{ mole } \text{AgBr}}{2 \text{ mole } \text{AgNO}_3} \times \frac{187.8 \text{ g } \text{AgBr}}{1 \text{ mole } \text{AgBr}}$$

$$= 111 \text{ g } \text{AgBr}$$

MgBr_2 is LR

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Percent composition

For ethanol, C_2H_5OH

molar mass C_2H_5OH

molar mass

$$2 \times 12.01 + 6 \times 1.008 + 1 \times 16.999 \quad C \quad 12.011$$

$$= 46.069 \text{ g/mol} \quad H \quad 1.008$$

of C_2H_5OH

$$O \quad 15.999$$

$$\%C = (24.022 \text{ g/mol} \div 46.069 \text{ g/mol}) \times 10^2$$

$$= 52.14 \%$$

$$\%H = (6.048 \text{ g/mol} \div 46.069 \text{ g/mol}) \times 10^2$$

$$= 13.13 \%$$

$$\%O = (15.999 \text{ g/mol} \div 46.069 \text{ g/mol}) \times 10^2$$

$$= 34.73 \%$$

$$\text{Sum} = 100 \%$$

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Q1 calculate the percent composition of R-22 chlorodifluoromethane, CHF_2Cl , the refrigerant used in home air conditioners.

* percent of element in a compound:

$$\begin{aligned} (\text{molar mass}) &= 35.5 + 2 \times 19 + 1 + 12 \\ &= 86.5 \end{aligned}$$

$$\%C = (12 \div 86.5) \times 10^2 = 13.9 \%$$

$$\%H = (1 \div 86.5) \times 10^2 = 1.15 \%$$

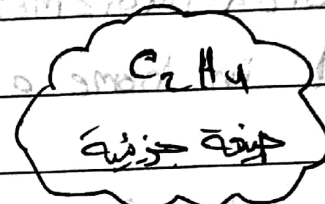
$$\%F = (2 \times 19 \div 86.5) \times 10^2 = 43.9 \%$$

$$\%Cl = (35.5 \div 86.5) \times 10^2 = 41 \%$$

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* Consider the following compounds

Ethylene C_2H_4



Propylene C_3H_6

Cyclobutane C_4H_8

Cyclohexane C_6H_{12}

* All have the same empirical formula CH_2

Empirical formula $\rightarrow$ a formula describing the lowest whole number ratio of atoms in a compound.

Ex.1 A white compound has been analyzed and found to contain 43.6 wt % phosphorous and 56.4% Oxygen. In separate study its molecular weight has been found to be 284 g/mol

what is the empirical formula of this compound?

*

Assume exactly 100 g of the compound, then one has

$$43.6 \text{ g P} \times \frac{1 \text{ mol P}}{30.974 \text{ g P}} = 1.408 \text{ mol of P}$$

$$56.4 \text{ g O} \times \frac{1 \text{ mol O}}{15.999 \text{ g O}} = 3.525 \text{ mol of O}$$

then the molar are

$$1.408 \text{ mol} \div 1.408 \text{ mol} = 1.000 \text{ mol P}$$

$$3.525 \text{ mol} \div 1.408 \text{ mol} = 2.503 \text{ mol O}$$

(the ratio to get the lowest whole number ratio 0.50? Multiply by 2

and the empirical formula is P_2O_5

* What do you do if you get a ratio with something that ends in

0.50 ? $\text{len} \times 2 = 1.00$

* Multiply by 2

0.33 or 0.66 ?

* Multiply by 3

0.25 or 0.75 ?

* Multiply by 4

0.20, 0.40, 0.60 or 0.80 ?

* Multiply by 5

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Ex| A white compound has been analyzed and found to contain 43.6 wt % phosphorous and 56.4 wt % oxygen. In a separate study its molecular weight has been found to be 284 g/mol

what is the molecular formula of this compound?

* First determine the empirical weight of P_2O_5 !

$$2 \times 30.974 \text{ g/mol P} = 61.948 \text{ g/mol P}$$

$$5 \times 15.999 \text{ g/mol O} = 79.997 \text{ g/mol O}$$

The empirical weight of P_2O_5 = the sum = 141.945 g/mol

$$\begin{aligned} \text{Molecular weight} &= \text{Empirical weight} \times 284 \text{ g/mol} \div 141.945 \text{ g/mol} \\ &= 2.001 \end{aligned}$$

and the molecular formula is twice the empirical formula and the molecular formula is P_4O_{10}

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Example: A white compound is analyzed and found to contain 45.2% C, 5.4% H, and 49.4% O by mass.

Mass to mole

Divide by small

Multiply 'til whole

1 mole C, 0.418 mole H, 3.075 mole O

1 mole C, 1 mole H, 7.8125 mole O

1 mole C, 1 mole H, 7.8125 mole O

1 mole C, 1 mole H, 7.8125 mole O

1 mole C, 1 mole H, 7.8125 mole O

Subject _____ Day _____ Date _____

If the odor of $C_6H_{10}S$ can be detected from 2×10^{-13} g in one liter of air, how many atom carbon of $C_6H_{10}S$?

$$\frac{2 \times 10^{-13} \text{ g}}{1 \times 10^{-9} \text{ g}} \times 1 \text{ molecule } C_6H_{10}S \times 6 \text{ atom carbon} = 6 \times 10^9 \text{ atom carbon}$$

Answer = 6×10^9 atom carbon

Q1 what is the molecular formula for a sample of compound that consists of 0.44 g hydrogen and 6.92 g oxygen? The molar mass of the compound is 34.06 g/mol.

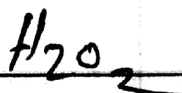
$$H \rightarrow \frac{0.44}{1} = 0.44 \text{ mol}$$

$$O \rightarrow \frac{6.92}{16} = 0.433 \text{ mol}$$

$$H \rightarrow 0.44 \div 0.433 \approx 1$$

$$O \rightarrow 0.433 \div 0.433 = 1$$

OH $\frac{1}{1}$ $\frac{1}{1}$



Subject _____ Day _____ Date _____

Properties of Gases Gas pressure

Gases are described in terms of four properties pressure (p), volume (V), temperature (T), and amount (n).

property	Description	unit of Measurement
pressure (p)	The force exerted by gas the walls of the container.	atmosphere (atm) mm, Hg pascal
volume (V)	the space occupied by the gas	Liter (L) milliliter (mL)
Temperature (T)	Determines the kinetic energy and rate of motion of the gas.	Celsius ($^{\circ}\text{C}$) Kelvin (K)
Amount	the quantity of gas present in a container	grams (g) moles (n)

Gas pressure is the force exerted by gas molecules on the walls of the container.

* is described as a force acting on a specific area.

$$\text{pressure (P)} = \frac{\text{Force}}{\text{Area}}$$

Has units of atm, mm Hg, Torr and Kilopascals (KPa)

قوة ضغط

مساحة

$$1 \text{ atm} = 760 \text{ mm Hg (exact)}$$

$$1 \text{ atm} = 760 \text{ Torr}$$

$$1 \text{ atm} = 101.325 \text{ KPa}$$

Q1 What is 475 mm Hg expressed in atm?

$$1) 475 \text{ atm}$$

$$2) 0.625 \text{ atm}$$

$$3) 3.61 \times 10^5 \text{ atm}$$

$$475 \text{ mm Hg} \times \frac{1 \text{ atm}}{760 \text{ mm Hg}}$$

$$= 0.625 \text{ atm}$$

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Q1 The pressure in a tire is 2.00 atm. What is this pressure in mm Hg?

1) 2.00 mm Hg

(851)

2) 1520 mm Hg

$$2 \text{ atm} \times \frac{760 \text{ mm Hg}}{1 \text{ atm}}$$

3) 22300 mm Hg

$$= 1520 \text{ mm Hg}$$

(892)

Atmospheric pressure الضغط الجوي

is the pressure exerted by a column of air from the top of the atmosphere to the surface of the Earth.

الضغط الجوي ↑

* is about 1 atmosphere at sea level.

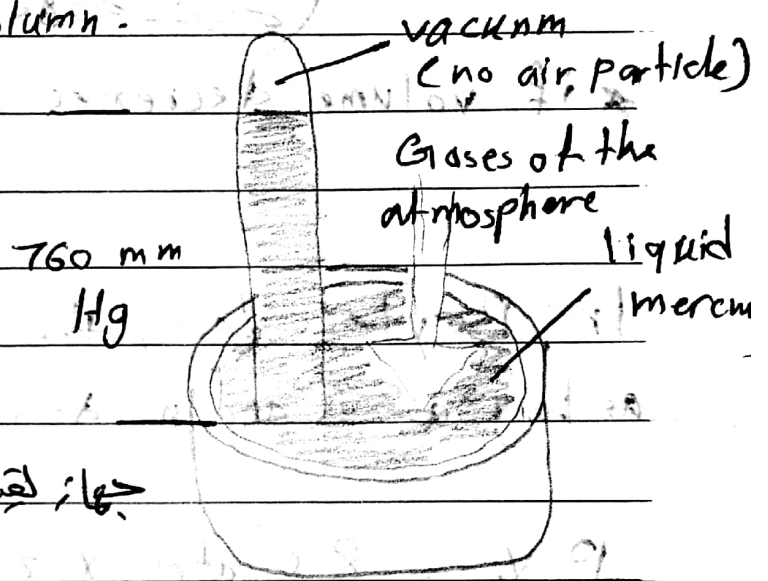
* depends on the altitude and the weather.

* is lower at high ~~alt~~ altitudes where the density of air is less.

* is higher on a rainy day than on a sunny day.

* measures the pressure exerted by the gases in the atmosphere.

* indicates atmospheric pressure as the height in mm of the mercury column.



A) The downward pressure of the Hg in a barometer is _____ than (as) the pressure of the atmosphere.

1) greater 2) less 3) the same

B) A water barometer is 13.6 times taller than a Hg barometer ($D_{Hg} = 13.6 \text{ g/ml}$) because:

1) H_2O is less dense than mercury

2) H_2O is heavier than mercury 3) air is more dense than H_2O

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Boyle's law states that :

* the pressure of a gas is inversely related to its volume when T and n are constant

(عكس التناسل) $P \propto \frac{1}{V}$

* if volume decreases, the pressure increases

In Boyle's law, the product $P \times V$ is constant as long as T and n do not change.

$$P_1 V_1 = 8.0 \text{ atm} \times 2.0 \text{ L} = 16 \text{ atm L}$$

$$P_2 V_2 = 4.0 \text{ atm} \times 4.0 \text{ L} = 16 \text{ atm L}$$

$$P_3 V_3 = 2.0 \text{ atm} \times 8.0 \text{ L} = 16 \text{ atm L}$$

Boyle's law can be stated as

$$P_1 V_1 = P_2 V_2 \quad (T, n \text{ constant})$$

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* The equation for Boyle's Law can be rearranged to solve for any factor.

$$P_1 V_1 = P_2 V_2$$

To solve for V_2 , divide both sides by P_2

$$V_2 = V_1 \frac{P_1}{P_2}$$

During an inhalation:

* the lungs expand

* the pressure in the lungs decreases.

* air flows towards the lower pressure in the lungs

Q1 Freon-12 CCl_2F_2 is used in refrigeration systems, what is the new volume (L) of a 8.0 L sample of freon gas initially at 550 mm Hg after its pressure is changed to 2200 mm Hg at constant T?

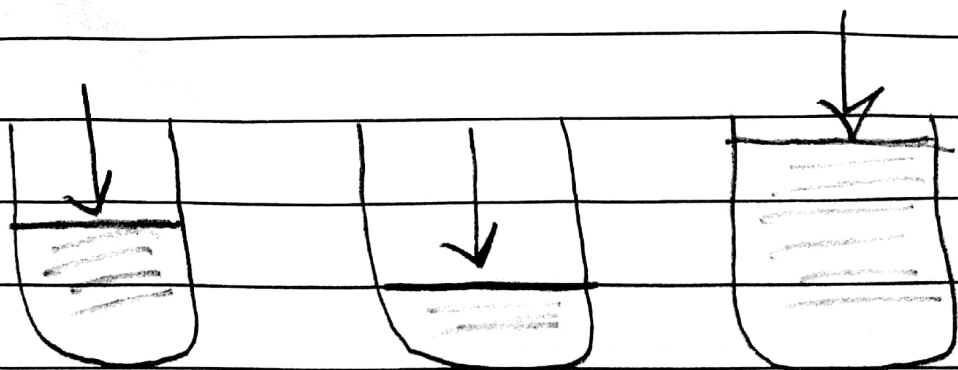
$$* P_1 V_1 = P_2 V_2$$

$$\frac{550 \text{ mm Hg} \times 8.0 \text{ L}}{2200 \text{ mm Hg}} = 2.0 \text{ L}$$

* For a cylinder containing helium gas indicate if cylinder A or cylinder B represents the new volume for the following changes (n and T are constant).

1) Pressure decreases (B)

2) pressure increases (A)



Initial $\rightarrow$ A or B

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Q1 If a sample of helium gas has a volume of 120 ml and a pressure of 850 mm Hg, what is the new volume if the pressure is changed to 425 mm Hg?

- 1) 60 ml 2) 120 ml 3) 240 ml

3)

$$P_1 V_1 = P_2 V_2$$

$$V_2 = 120 \text{ ml} \times \frac{850 \text{ mm Hg}}{425 \text{ mm Hg}}$$

$$V_2 = 240 \text{ ml}$$

15.5

15.5

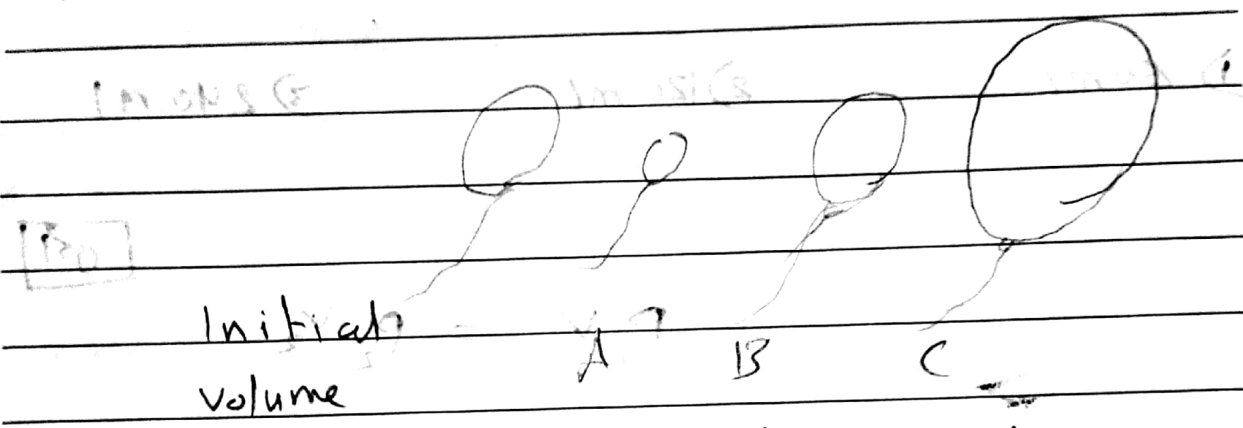
15.5

15.5

$$P_1 V_1 = P_2 V_2$$

$$V_2 = 120 \text{ ml} \times \frac{850}{425}$$

Q1. A sample of helium gas in a balloon has a volume of 6.4 at a pressure of 0.70 atm. At 1.40 atm (T constant), is the new volume represented by A, B or C?



* the new volume is represented by the smaller balloon A.

Q1 If the sample of helium gas has a volume of 6.4 L at a pressure of 0.70 atm, what is the new volume when the pressure is increased to 1.40 atm?

- A) 3.2 L B) 6.4 L C) 12.8 L

$$V_1 P_1 = V_2 P_2$$

$$6.4 \text{ L} \times \frac{0.70 \text{ atm}}{1.40 \text{ atm}}$$

Charles's Law: The volume of a gas is directly related to its temperature (K) of a gas is directly related to its volume.

الكمية (الغاز) $\propto$ (الدرجة) $\rightarrow$ $V \propto T$

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

* pressure and moles of gas are constant. = P

* when the temperature of a sample of gas increase its volume increases at constant pressure.

Imp of $\propto$ $\rightarrow$ $V \propto T$ $\rightarrow$ $V = kT$

For two conditions, Charles's law is written (P and n are constant)

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

Rearranging Charles's law to solve for V_2 :

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

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

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Q1 A balloon has a volume of 785 ml at 21°C . If the temperature drops to 0°C , what is the new volume of the balloon at constant pressure and moles?

$$T_1 = 21^{\circ}\text{C} = 294\text{ K}$$

$$T_2 = 0^{\circ}\text{C} = 273\text{ K}$$

$$V_2 = 785\text{ ml} \times \frac{273\text{ K}}{294\text{ K}} = 729\text{ ml}$$

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

Subject _____ Day _____ Date _____

* the pressure exerted by a gas is directly related to the Kelvin temperature.

V and n are constant.

(الكمية ثابتة)

كمالات درجة الحرارة تزداد

(الضغط يزداد)

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Q | A gas has a pressure at 2.0 atm at 18°C. what is the new pressure when the temperature is 62°C?

$$* P_1 = 2.0 \text{ atm}$$

$$P_2 = ?$$

$$T_1 = 18^\circ\text{C} + 273 \\ = 291 \text{ K}$$

$$T_2 = 62^\circ\text{C} + 273 \\ = 335 \text{ K}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = P_1 \times \frac{T_2}{T_1}$$

$$P_2 = 2.0 \text{ atm} \times \frac{335 \text{ K}}{291 \text{ K}} = 2.3 \text{ atm}$$

Q1] A gas has a pressure of 645 torr at 128°C. What is the temperature in Celsius if the pressure increases to 1.50 atm (n and V remain constant)?

$$* P_1 = 645 \text{ torr}$$

$$P_2 = 1.50 \text{ atm} \times \frac{760 \text{ torr}}{1 \text{ atm}}$$

$$P_2 = 1140 \text{ torr}$$

$$T_1 = 128^\circ\text{C} + 273$$
$$= 401 \text{ K}$$

$$T_2 = \text{K} - 273$$
$$= ?^\circ\text{C}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$T_2 = T_1 \times \frac{P_2}{P_1}$$

$$T_2 = 401 \text{ K} \times \frac{1140 \text{ torr}}{645 \text{ torr}} = 709 \text{ K}$$

$$709 \text{ K} - 273 = 436^\circ\text{C}$$

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The combined gas law uses Boyle's Law, Charles' Law, and Gay-Lussac's Law (n is constant)

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad (\text{القانون العام})$$

Q1 A gas has a volume of 675 ml at 35°C and 0.850 atm pressure. what is the volume (ml) of the gas at -95°C and a pressure of 802 mmHg?

$$* T_1 = 35^\circ\text{C} + 273$$

$$T_1 = 308 \text{ K}$$

$$T_2 = -95^\circ\text{C} + 273$$

$$T_2 = 178 \text{ K}$$

$$V_1 = 675 \text{ ml}$$

$$V_2 = ??$$

$$P_1 = 646 \text{ mm Hg}$$

$$P_2 = 802 \text{ mm Hg}$$

$$V_2 = V_1 \times \frac{P_1}{P_2} \times \frac{T_2}{T_1}$$

$$V_2 = 675 \text{ ml} \times \frac{646 \text{ mm Hg}}{802 \text{ mm Hg}} \times \frac{178 \text{ K}}{308 \text{ K}}$$

$$V_2 = 314 \text{ ml}$$

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Q1 A sample of helium gas has a volume of 0.180 L, a pressure of 0.800 atm and a temperature of 29°C. At what temperature (°C) will the helium have a volume of 90.0 ml and a pressure of 3.20 atm

$$1 \text{ L} = 1000 \text{ ml}$$

$$* P_1 = 0.800 \text{ atm} \quad P_2 = 3.20 \text{ atm}$$

$$V_1 = 0.180 \text{ L} \quad (180 \text{ ml}) \quad V_2 = 90.0 \text{ ml}$$

$$T_1 = 29^\circ\text{C} + 273 = 302 \text{ K} \quad T_2 = ??$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$T_2 = T_1 \times \frac{P_2}{P_1} \times \frac{V_2}{V_1}$$

$$T_2 = 302 \text{ K} \times \frac{3.20 \text{ atm}}{0.800 \text{ atm}} \times \frac{90.0 \text{ ml}}{180 \text{ ml}} = 604 \text{ K}$$

$$T_2 = 604 \text{ K} - 273 = 331^\circ\text{C}$$

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Avogadro's Law

* the volume of a gas is directly related to the number of moles (n) of gas.

* T and P are constant

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

كل ذرة، حجم واحد، نفس الحجم

Q1 If 0.75 mole helium gas occupies a volume of 1.5 L, what volume will 1.2 mole helium occupy at the same temperature and pressure?

1) 0.94 L

2) 1.8 L

3) 2.4 L

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

$$V_2 = 1.5 \text{ L} \times \frac{1.2 \text{ moles He}}{0.75 \text{ mole He}}$$

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The volumes of gases can be compared at STP standard temperature and pressure, when they have

- * the same temperature
standard temperature (T)
 0°C or 273K

- * the same pressure
standard pressure (P)
 1atm (760 mmHg)

At standard temperature and pressure (s) 1 mole of a gas occupies a volume of 22.4 which is called its molar volume.

Subject _____ Day _____ Date _____

The molar volume at STP can be used to form conversion factors

$$\frac{22.4 \text{ L}}{1 \text{ mole}} \quad \text{and} \quad \frac{1 \text{ mole}}{22.4 \text{ L}}$$

what is the volume occupied by 2.75 moles N_2 gas at STP?

* The molar volume is used to convert moles to liters.

Molar of gas $\leftarrow$ Molar volume $\rightarrow$ volume
(91) gas $\leftarrow$ 22.4 L/mol $\rightarrow$ volume of gas

$$2.75 \text{ moles } \text{N}_2 \times \frac{22.4 \text{ L}}{1 \text{ mole}} = 61.6 \text{ L}$$

Subject

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A) what is the volume at STP at 4.00 g of ethane

1) ~~2.60 L~~

2) 11.2 L

3) 44.8 L

4) 5.60 L

B) How many grams of He are present in 8.00 L of gas at STP?

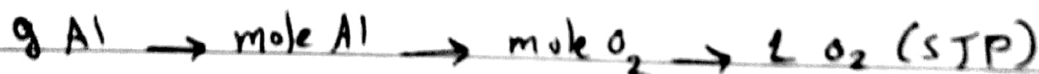
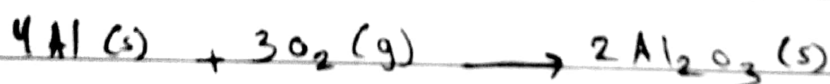
1) 25.6 g

2) 0.357 g

3) ~~1.43 g~~

4) 1.43 g

C) what volume (L) of O_2 gas is needed to completely react with 15.0 g of aluminum at STP?

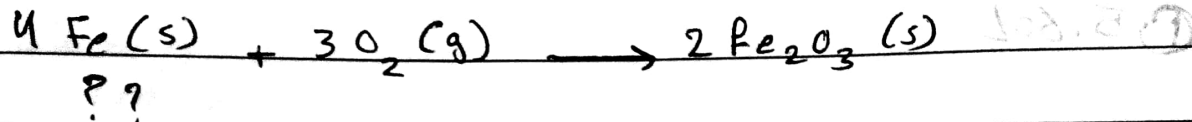


$$15.0\ g\ Al \times \frac{1\ \text{mole Al}}{27.0\ g\ Al} \times \frac{3\ \text{moles } O_2}{4\ \text{moles Al}} \times \frac{22.4\ L\ (STP)}{1\ \text{mole } O_2}$$

$$= 9.33\ L\ O_2\ \text{at STP}$$

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What mass of Fe will react with 5.50 L O₂ at STP?



$$5.50 \text{ L O}_2 \times \frac{1 \text{ mole}}{22.4 \text{ L}} \times \frac{4 \text{ moles Fe}}{3 \text{ moles O}_2} \times \frac{55.9 \text{ g Fe}}{1 \text{ mole Fe}}$$

$$= 18.3 \text{ g}$$

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Boyles law $V \propto \frac{1}{P}$

Charles law $V \propto T$

Avogadro's law $V \propto n$

Combining these, we get $V \propto \frac{nT}{P}$ $k \rightarrow R$

Then $V = \frac{nRT}{P}$ or $PV = nRT$
 R (constant)

$$R = \frac{PV}{nT}$$

في الظروف القياسية

$$R = \frac{(1.00 \text{ atm})(22.4 \text{ L})}{(1 \text{ mole})(273 \text{ K})} = \frac{0.0821 \text{ L atm}}{\text{mole K}}$$

مثال

$$R = \frac{(760 \text{ mmHg})(22.4 \text{ L})}{(1 \text{ mole})(273 \text{ K})} = \frac{62.4 \text{ L mmHg}}{\text{mole K}}$$

Q1 Dinitrogen oxide N_2O , which is used in dentistry, is an anesthetic also called laughing gas. what is the pressure in atmosphere of 0.350 mole of N_2O at $22^\circ C$ in a 5.00-L container

$$* PV = nRT \quad T = 22^\circ C + 273 = 295 K$$

$$P = \frac{nRT}{V}$$

$$P = 0.350 \text{ mole} \times \frac{0.0821 \text{ L atm}}{5.00 \text{ L} \times \cancel{\text{mole}}} \times 295 K$$

$$P = 1.70 \text{ atm}$$

Ideal Gas Constant (R)	0.0821 L atm mole · K	62.4 L · mmHg mole · K
Pressure (P)	atm	mmHg
Volume (V)	L	L
Amount (n)	moles	moles
Temperature (T)	K	K

Subject _____ Day _____ Date _____

Q) A 5.0 cylinder gas contains oxygen gas at 20.0°C and 735 mmHg . How many grams of oxygen are in the cylinder?

$$n = \frac{PV}{RT}$$

$$n = \frac{(735\text{ mmHg})(5.0\text{ L})(\text{mol}\cdot\text{K})}{(62.4\text{ mmHg}\cdot\text{L})(293\text{ K})}$$

$$n = 0.2\text{ mol O}_2$$

$$\text{So in grams} = 0.2\text{ mol O}_2 \times \frac{32.0\text{ g O}_2}{1\text{ mol O}_2} = 6.4\text{ g}$$

Q1 what is the molar mass of a gas if 0.250 of the gas occupy 215 ml at 0.813 atm and 30.0°C ?

$$* n = \frac{PV}{RT}$$

$$n = \frac{(0.813 \text{ atm}) (0.215 \text{ L}) (\text{mol} \cdot \text{K})}{(0.0821 \text{ atm} \cdot \text{L}) (303 \text{ K})}$$

$$n = 0.00703 \text{ mol}$$

$$\text{Mol} = \frac{\text{mass}}{\text{molar mass}}$$

$$\text{Molar mass} = \frac{0.250 \text{ g}}{0.00703 \text{ mol}} = 35.6 \text{ g/mol}$$

Subject _____ Day _____ Date _____

* Calculate the density in g/L of oxygen gas at STP.

$$* PV = nRT$$

$$\frac{PV}{RTV} = \frac{nRT}{RTV}$$

$$\frac{P}{RT} = \frac{n}{V}$$

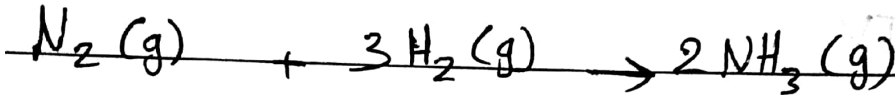
density = mass / volume

$$\frac{P}{RT} = \frac{\text{mass}}{V} \div \text{molar mass} \rightarrow \text{density} = \frac{\text{Molar mass} \times P}{RT}$$

$$\text{Density} = \frac{32.0 \text{ g/mol (molar mass)} \times 1.00 \text{ atm}}{(0.0821 \text{ atm}\cdot\text{L}) (273 \text{ K})}$$

$$= 1.43 \text{ g/L}$$

Nitrogen gas reacts with hydrogen gas to produce ammonia (NH_3) gas. How many liters of NH_3 can be produced at 0.93 atm and 24°C from a 16.0 g sample of nitrogen gas and an excess of hydrogen gas?



$$* \quad n = \frac{PV}{RT}$$

$$16.0 \text{ g N}_2 \times \frac{1 \text{ mole N}_2}{28.02 \text{ g N}_2} \times \frac{2 \text{ moles NH}_3}{1 \text{ mole N}_2}$$

$$= 1.14 \text{ moles NH}_3$$

Dalton's law)

the total pressure exerted by gases in a mixture is the sum of the partial pressures of gases!

$$P_T = P_1 + P_2 + P_3$$

For example, at STP, one mole of a pure gas in a volume of 22.4 L will exert the same pressure as one mole of a gas mixture in 22.4 L

V = 22.4 L		
	0.6 mole He	0.5 mole O ₂
1.0 mole N ₂	0.4 mole O ₂	0.3 mole He
	1.0 mole	0.2 mole Ar
1.0 atm	1.0 atm	1.0 atm

Subject _____ Day _____ Date _____

Q/A scuba tank contains O_2 with a pressure of 0.450 atm and He at 855 mm Hg. What is the total pressure in mmHg in the tank?

$$* \quad 0.450 \text{ atm} \times \frac{760 \text{ mmHg}}{1 \text{ atm}}$$

$$= 342 \text{ mmHg} = P_{O_2}$$

$$P_{\text{total}} = P_{O_2} + P_{\text{He}} \quad O_2 < He$$

$$342 \text{ mmHg} + 855 \text{ mmHg}$$

$$= 1197 \text{ mmHg}$$

Subject _____ Day _____ Date _____

Q1 For a deep dive, a scuba diver uses a mixture of helium and oxygen with a pressure of 8.00 atm. If the oxygen has a partial pressure of 1280 mm Hg. what is the partial pressure of the helium?

- 1) 520 mm Hg
- 2) 2040 mm Hg
- 3) 4800 mm Hg

حل

$$P_{\text{total}} = 8.00 \text{ atm} \times \frac{760 \text{ mm Hg}}{1 \text{ atm}} = 6080 \text{ mm Hg}$$

$$P_{\text{total}} = P_{\text{O}_2} + P_{\text{He}}$$

$$P_{\text{He}} = P_{\text{total}} - P_{\text{O}_2}$$

$$P_{\text{He}} = 6080 \text{ mm Hg} - 1280 \text{ mm Hg} \\ = 4800 \text{ mm Hg}$$

Subject _____ Day _____ Date _____

$$P_{\text{total}} = P_{O_2} + P_{He} \quad P V = n R T$$

$$\frac{n_{O_2} R T}{V} + \frac{n_{He} R T}{V}$$

$$P_{\text{total}} = (n_{O_2} + n_{He}) \frac{R T}{V}$$

(B)

Answer: $P_{O_2} = 0.2 \text{ atm}$ $P_{He} = 0.8 \text{ atm}$

$$P_{O_2} = 0.2 \text{ atm}$$

$$P_{He} = 0.8 \text{ atm}$$

$$P_{O_2} = 0.2 \text{ atm}$$

$$P_{He} = 0.8 \text{ atm}$$

Subject _____ Day _____ Date _____

Q1 A 5.0 L scuba tank contains 1.05 mole of O_2 and 0.418 mole He, at $25^\circ C$. What is the partial pressure of each gas, and what is the total pressure in atm in the tank?

$$P_{\text{total}} = P_{O_2} + P_{He}$$

$$= \frac{n_{O_2} R T}{V} + \frac{n_{He} R T}{V}$$

$$= \frac{1.05 \text{ mol} \times 0.0821 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol} \times 298 \text{ K}}{5.0 \text{ L}} + \frac{0.418 \text{ mol} \times 0.0821 \times 298}{5.0 \text{ L} (\text{K} \cdot \text{mol})}$$

$$= 5.14 \text{ atm} + 2.05 \text{ atm}$$

$$= 7.19 \text{ atm}$$

$$\text{or } P_{\text{total}} = (n_{O_2} + n_{He}) \frac{R T}{V} = 7.19 \text{ atm}$$

Subject _____ Day _____ Date _____

Q1) A gaseous mixture made from 6.00 g O_2 and 9.00 g CH_4 is placed in a 15.0 L vessel at $0^\circ C$. What is the partial pressure of each gas and what is the total pressure in the vessel?

$$n_{O_2} = (6.00 \text{ g } O_2) \left(\frac{1 \text{ mol } O_2}{32.0 \text{ g } O_2} \right) = 0.188 \text{ mol } O_2$$

$$n_{CH_4} = (9.00 \text{ g } CH_4) \left(\frac{1 \text{ mol } CH_4}{16.0 \text{ g } CH_4} \right) = 0.563 \text{ mol } CH_4$$

$$P_{O_2} = \frac{n_{O_2} RT}{V} = \frac{(0.188 \text{ mol})(0.0821 \text{ L-atm/mol-K})(273 \text{ K})}{15.0 \text{ L}}$$

$$= 0.281 \text{ atm}$$

$$P_{CH_4} = \frac{n_{CH_4} RT}{V} = \frac{(0.563 \text{ mol})(0.0821 \text{ L-atm/mol-K})(273 \text{ K})}{15.0 \text{ L}}$$

$$= 0.841 \text{ atm}$$

$$P_{\text{total}} = 0.281 \text{ atm} + 0.841 \text{ atm} = 1.122 \text{ atm}$$

(9) 24/26

Subject _____ Day _____ Date _____

$$\frac{P_i}{P_{\text{total}}} = \frac{n_i}{n_{\text{total}}} \frac{RT}{RT}$$

$$PV = nRT \text{ so } P = \frac{nRT}{V}$$

$$\frac{P_i}{P_{\text{total}}} = \frac{n_i}{n_{\text{total}}} \text{ and we know that mol fraction}$$

$$X = \frac{n_i}{n_{\text{total}}}$$

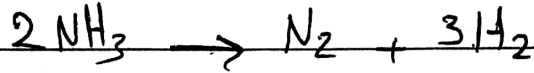
$$\frac{P_i}{P_{\text{total}}} = X \rightarrow P_i = X P_{\text{total}}$$

$$\frac{n_i}{n_{\text{total}}} = \frac{P_i}{P_{\text{total}}}$$

$$\frac{S}{N} = \frac{P}{P_{\text{total}}}$$

$$\frac{S}{N} = \frac{P}{P_{\text{total}}}$$

Q) NH_3 decomposes to N_2 and H_2 as



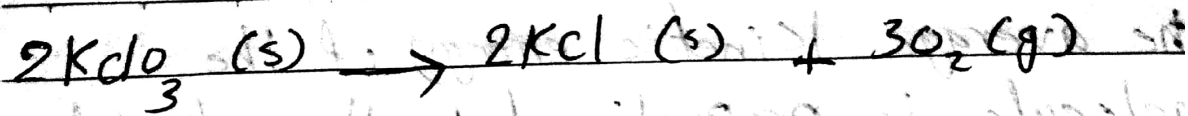
18.4 atm of NH_3 was initially decomposed, calculate the total pressure in the container when the reaction is finished (assume the volume and temperature in the container are constant).

- a) 2.0 atm
- b) 10.0 atm
- c) 8.0 atm
- d) 6.0 atm

$$\frac{P_1}{P_{\text{total}}} = \frac{n_1}{n_{\text{total}}}$$

$$\frac{4}{P_{\text{total}}} = \frac{2}{4}$$

$$P_{\text{total}} = 8 \text{ atm}$$



$$P_T = P_{\text{O}_2} + P_{\text{H}_2\text{O}}$$

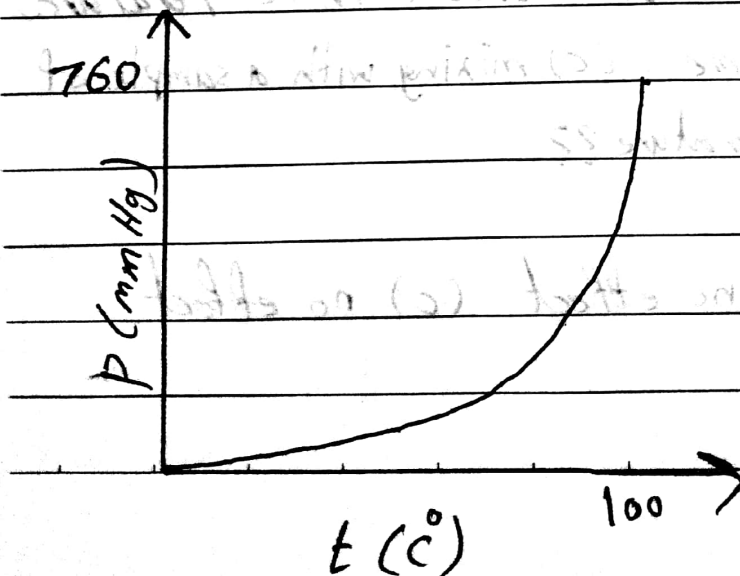
نلاحظ ان الضغط الكلي يساوي مجموع ضغطي الغازين

* Oxygen gas generated by the decomposition of potassium is collected.

* The volume of oxygen collected at 24°C and atmospheric pressure of 762 mmHg is 128 ml .

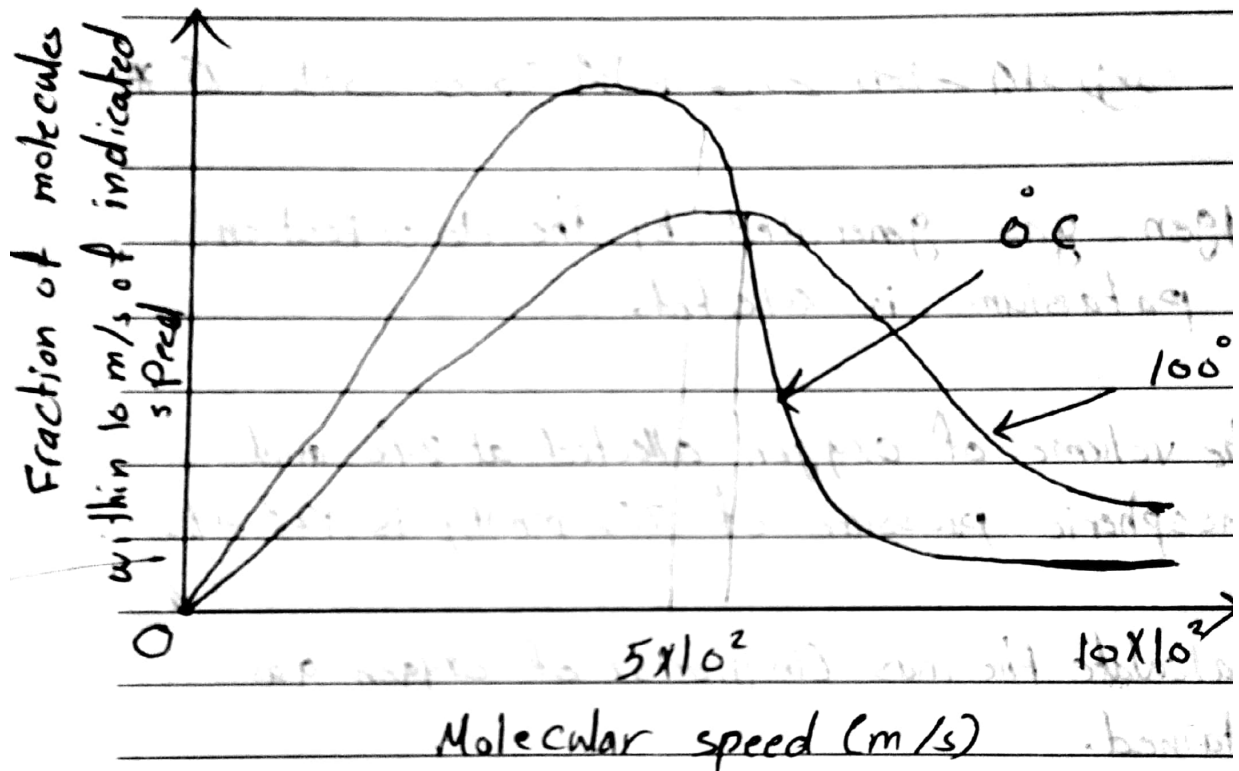
* calculate the mass (in grams) of oxygen gas obtained.

[Hint] the pressure of the water vapor at 24°C is 224 mmHg .



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The average kinetic energy of the molecules is proportional to the absolute temperature.



Q How is the speed of N_2 molecules in a gas sample changed by (a) an increase in temperature (b) an increase in volume, (c) mixing with a sample of Ar at the same temperature??

* (a) increases (b) no effect (c) no effect

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Effusion - Coolidge

* the escape of gas molecules through a tiny hole an evacuated space.

* the spread of one substance throughout a space or throughout a second substance.

* Average molecular kinetic energy depends only on temperature for ideal gases.

Therefore:

* Higher temperature means higher root-mean-square speed (RMS), v_{rms}

* The higher the molecular weight (molar mass), the lower the v_{rms} speed (same temperature).

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Calculate the rms speed, u of an N_2 molecule at $25^\circ C$.

$$u_{rms} = \sqrt{\frac{3RT}{M}}$$

$$T = 25 + 273 = 298 K$$

$$M = 28.0 \text{ g/mol} = 28.0 \times 10^{-3} \text{ Kg/mol}$$

$$R = 8.314 \text{ J/mol-K} = 8.314 \text{ Kg-m}^2/\text{s}^2\text{-mol-K}$$

(These units follow the fact that $1 \text{ J} = 1 \text{ Kg-m}^2/\text{s}^2$)

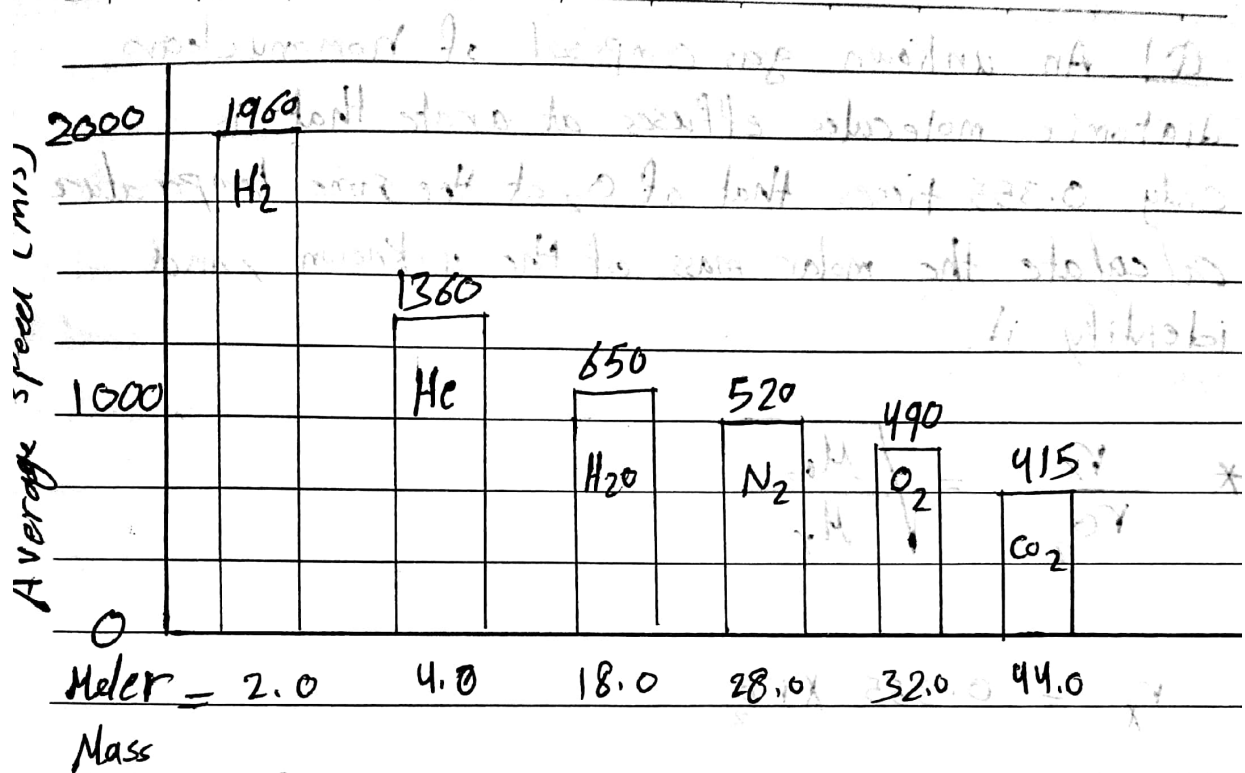
$$u = \sqrt{\frac{3(8.314 \text{ Kg-m}^2/\text{s}^2\text{-mol-K})(298 \text{ K})}{28.0 \times 10^{-3} \text{ Kg/mol}}}$$

$$u = 5.15 \times 10^2 \text{ m/s}$$

Q1 what is the rms speed of an He at $25^\circ C$?

$$* 1.36 \times 10^3 \text{ m/s}$$

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أُسرع جزيء H_2 - العلاقة بين الكتلة المولية والسرعة.

(20°C) - 281.0

(5.1)

281.0 - 651.0

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Q1 An unknown gas composed of homonuclear diatomic molecules effuses at a rate that is only 0.355 times that of O_2 at the same temperature. Calculate the molar mass of the unknown, and identify it.

$$\frac{r_x}{r_{O_2}} = \sqrt{\frac{M_{O_2}}{M_x}}$$

$$r_x = 0.355 \times r_{O_2}$$

$$\frac{r_x}{r_{O_2}} = 0.355 = \sqrt{\frac{32.0 \text{ g/mol}}{M_x}}$$

$$(0.355)^2 = \frac{32.0 \text{ g/mol}}{M_x} = 0.126$$

(I₂)

$$M_x = \frac{32.0 \text{ g/mol}}{0.126} = 254 \text{ g/mol}$$

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Intermolecular Forces and Liquids and Solids

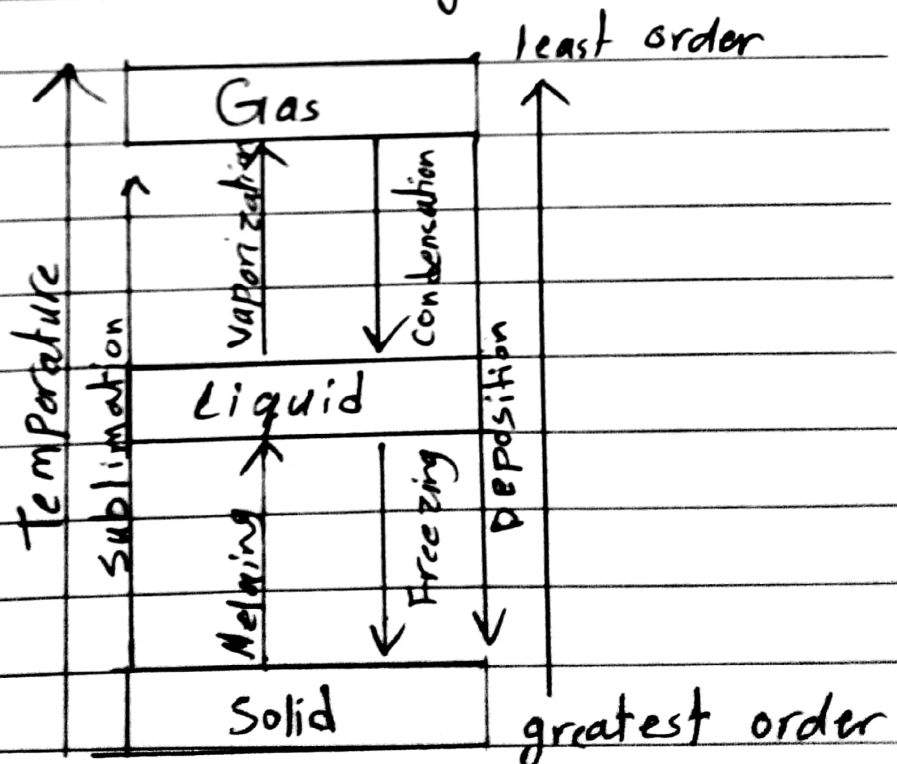
A phase is a homogeneous part of the system in contact with other parts of the system but separated from them by a well-defined boundary.

2 phases

Solid phase = ice

Liquid phase = water

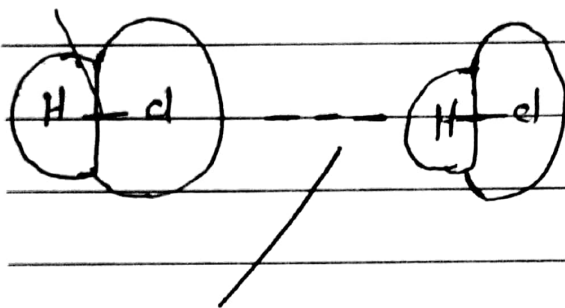
Phase changes



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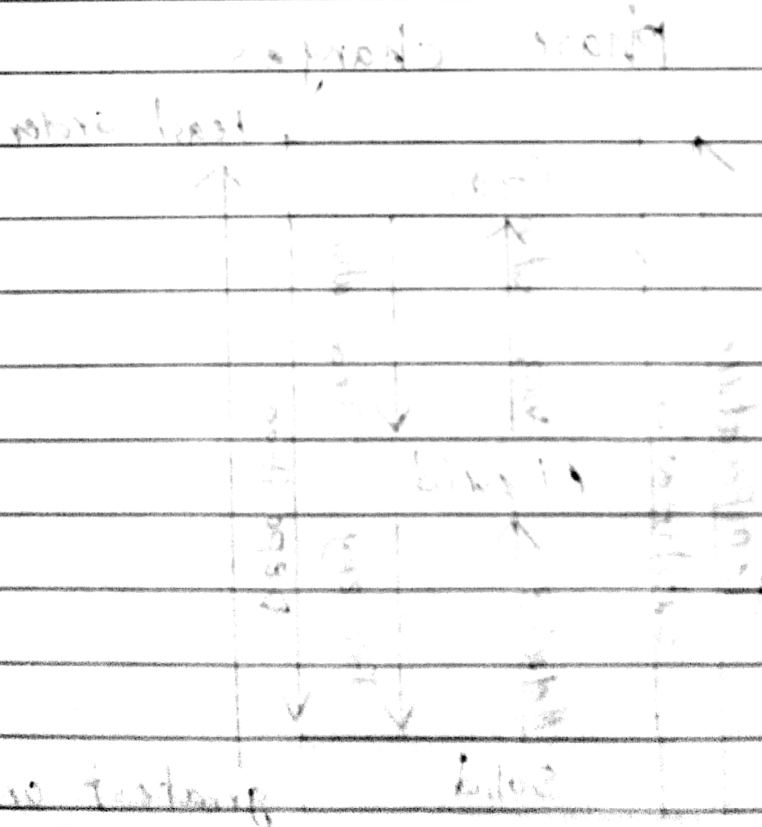
Intermolecular Forces

* are in general much weaker than intramolecular forces.
covalent bond (strong)



intermolecular forces are generally less than 15% as strong as ionic or covalent bonds.

Intermolecular attraction (weak)



Intermolecular Forces

- * are attractive forces between molecules.
- * hold atoms together in a molecule
(ionic bond NaCl and Covalent bond HCl)

Intermolecular vs Intramolecular

- 41 J to vaporize 1 mole of water (inter)
- 930 KJ to break all O-H bonds in 1 mole of water (intra)

* intermolecular forces are much weaker than intramolecular forces.

"Measure of intermolecular force"

boiling point

melting point

ΔH_{vap}

ΔH_{fus}

ΔH_{sub}

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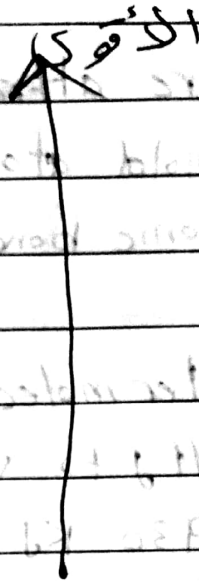
What are Intermolecular Forces?

1) Ion-dipole (strongest)

2) hydrogen bonding

3) dipole-dipole

4) dispersion (weakest)



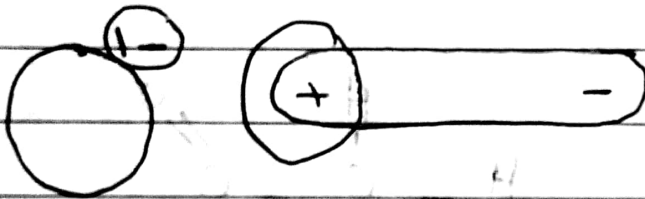
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Ion - Dipole Forces

Attractive forces between an ion and a polar molecule.



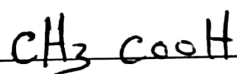
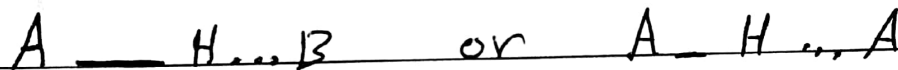
* the attachment of water to solute particle is called hydration, hydration of ions is due to the polar character of the H_2O molecule.

* Hydrogen bonding is a weak to moderate attractive force that exists between a hydrogen atom covalently bonded to a very small and highly electronegative atom and a lone pair of electrons on another small electronegative atom (F, O, or N).

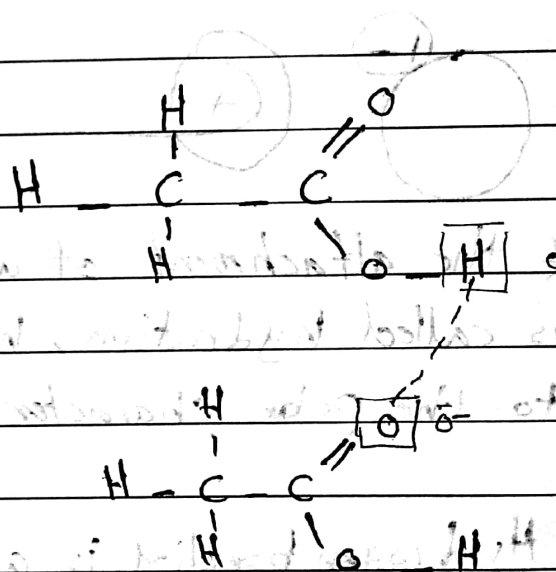
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Hydrogen Bond

* the hydrogen bond is a special dipole-dipole interaction between the hydrogen atom in a polar N-H, O-H, or F-H bond and an electronegative O, N or F atom.

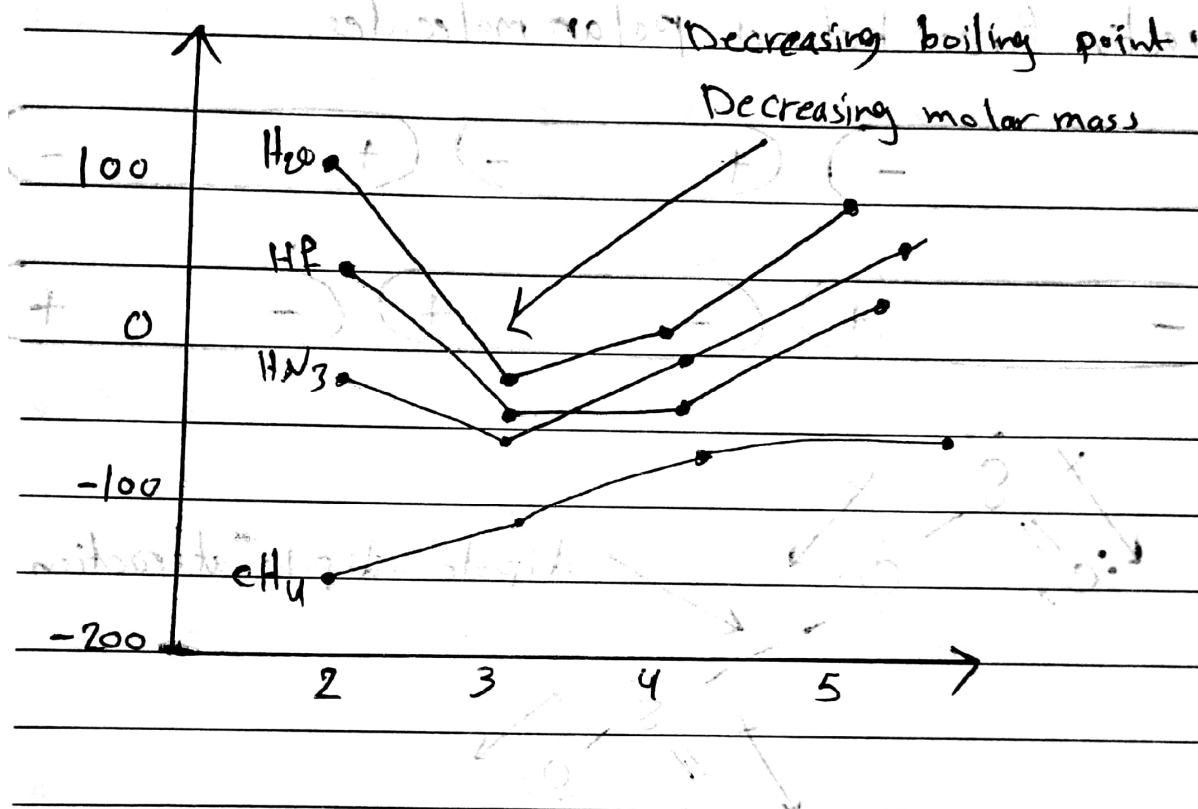


Acetic acid

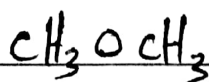


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Q1 why is the hydrogen bond considered a "special" dipole-dipole interaction?



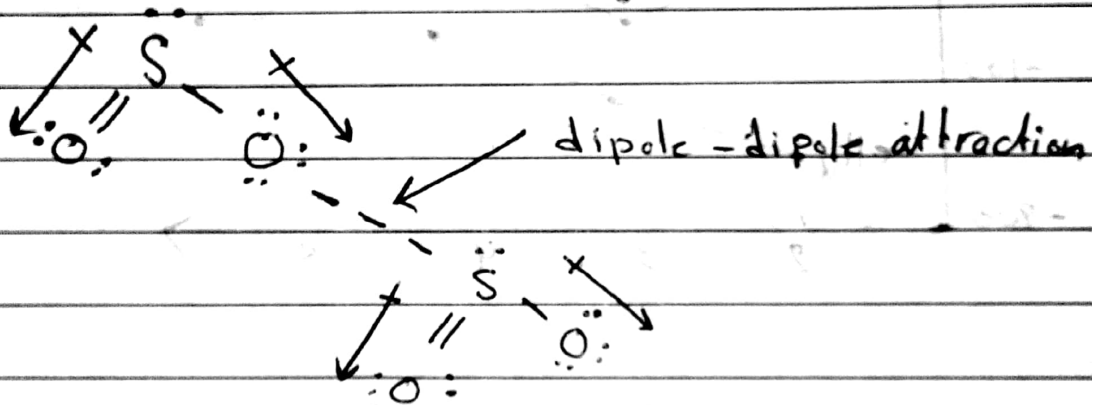
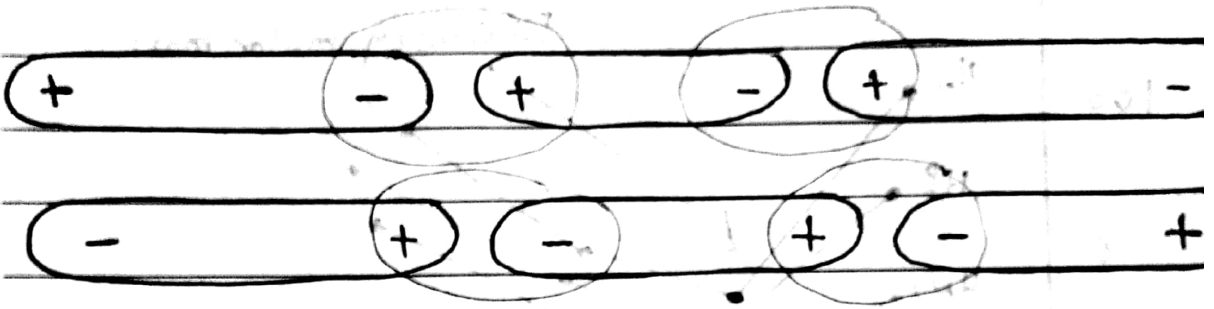
Q2 which of the following can form hydrogen bonds with water?



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Dipole - Dipole Forces

Attractive forces between polar molecules.



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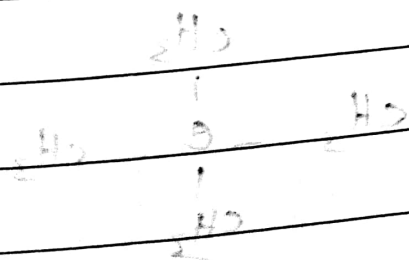
Dispersion Forces

* usually forces increase with molar mass.

(Factors Affecting London Forces)

* the shape of the molecule affects the strength of dispersion forces: long, skinny molecules (like n-pentane) tend to have stronger dispersion forces than short, fat ones (like neopentane)

* this is due to the increased surface area in n-pentane.



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Factors that affect boiling point

1. Intermolecular forces

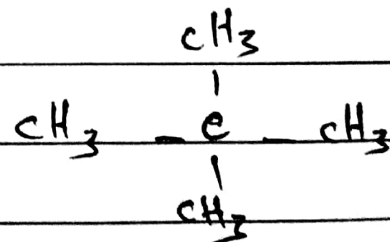
London dispersion forces < Dipole-Dipole interaction < Hydrogen

2. Number of sites for intermolecular interaction
(surface area)

Larger surface (more electrons) $\rightarrow$ more sites for London
 $\rightarrow \uparrow$ b.p. $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 > \text{CH}_3 - \text{CH}_2 - \text{CH}_3$

3. Molecular shape : the same molecular weight

linear $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 >$ spherical



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Rod-like molecules

have a greater surface area, more contact points for molecules to join together.

Ball or spherical

shaped molecules have a fewer contact points for molecules to join together.

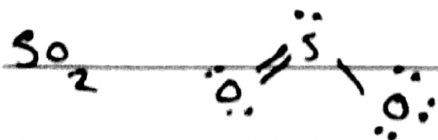
Boiling points: 36°C

isomers 10°C

What type of intermolecular forces exist between each of the following molecules?

HBr (is a polar molecule: dipole-dipole forces. There are also dispersion forces between HBr molecules)

CH_4 (is nonpolar: dispersion forces)



(is a polar molecule: dipole-dipole forces. There are also dispersion forces between SO_2 molecules)

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Q1 what type of intermolecular forces exist between the following pairs?

1. HBr and H_2S

* are polar molecules. Therefore, the intermolecular forces present are dipole - dipole forces, as well as dispersion forces.

2. Cl_2 and CBr_4

* are nonpolar, so there are only dispersion forces between these molecules.

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Properties of Liquids

1. Viscosity
2. Surface tension
3. Cohesive and adhesive Forces
4. Vapor pressure

(viscosity)

- Resistance of a liquid to flow is called viscosity
- It is related to the ease with which molecules can move past each other.
- Viscosity increases with stronger intermolecular forces and decreases with higher temperature.

strong intermolecular → High viscosity

(surface tension) is the amount of energy required to stretch or increase the surface of a liquid by a unit area.

strong intermolecular forces $\rightarrow$ High surface tension

* Surface tension For

$\text{Hg} > \text{H}_2\text{O} > \text{CH}_3\text{OCH}_3$ surface tension increases with stronger intermolecular.

Cohesion $\rightarrow$ is the intermolecular attraction between like molecules (bind molecules of the same type together)

Adhesion $\rightarrow$ is an attraction between unlike molecules (bind substance to surface)

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(capillary action) is how liquids flow up narrow tubes.

The upward curved meniscus of water forms (concave مقعر) because water binds to glass.

Adhesion > cohesion ← الماء

The downward meniscus of mercury forms (convex محدب) because the cohesive forces in mercury is stronger than between mercury atoms and the glass.

cohesion > Adhesion ← الزئبق

السوائل ترتفع في الأنابيب الضيقة.

(vapor pressure)

البخار أكثر عندما تكون الحرارة عالية.

إذا كانت الروابط قوية لا يوجد بخار.

أقوى الروابط هي الهيدروجين.

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* The normal boiling point is the temperature at which its vapor pressure is 760 torr.

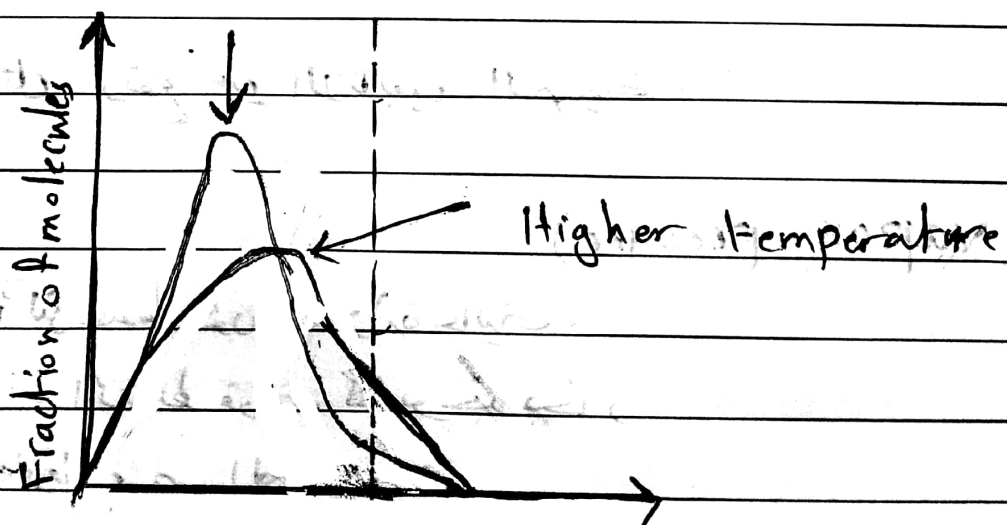
* Liquids in which the intermolecular forces are strong have relatively low vapor pressure.

* Vapor pressure increases significantly with temperature.

* At any temperature, some molecules in liquid have enough energy to escape.

* As the temperature rises, the fraction of molecules that have enough to escape increases.

Lower temperature



* The boiling point (B.P.) for a liquid gives indication about its vapor pressure (the liquid with higher boiling point will have lower vapor pressure)

Q1 which one of liquid have highest vapor pressure.

① $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$ B.P $\rightarrow 34.5^\circ\text{C}$

• $\text{CH}_3\text{CH}_2\text{OH}$ B.P $\rightarrow 78.5^\circ\text{C}$

• H_2O B.P $\rightarrow 100^\circ\text{C}$

• $\text{HOCH}_2\text{CH}_2\text{OH}$ B.P $\rightarrow 198^\circ\text{C}$

الانقار درجة غليان (جنا، أكثر)

• $\rightarrow$ (المسوحة ضوئياً)

Clausius Clapeyron Equation

$$\ln \frac{P_{\text{vap } T_1}}{P_{\text{vap } T_2}} = \frac{\Delta H}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

or

$$\ln \frac{P_1}{P_2} = \frac{\Delta H}{R} \left(\frac{T_1 - T_2}{T_1 T_2} \right)$$

P_{vap} : vapor pressure.

ΔH_{vap} : enthalpy of vaporization.

* R : 8.3145 J/K mol

T : temperature (in kelvin)

Q1) what is the vapor pressure of water at 100°C ?

* 760 torr

Q1) The vapor pressure of water at 25°C is 23.8 torr, and the heat of vaporization of water at 25°C is 43.9 kJ/mol . calculate the vapor pressure of water at 65°C .

* 194 torr

Q1) In the heat of vaporization of water (ΔH_v) is 40.7 kJ/mol . calculate the vapor pressure of pure water at 73°C .

* 273 torr

Q1 Diethyl ether $[(C_2H_5)_2O]$ is a volatile, highly flammable organic liquid that is used mainly as a solvent.

The vapor pressure of diethyl ether is 401 mmHg at $18^\circ C$. Calculate its vapor pressure at $32^\circ C$.

$$* P_1 = 401 \text{ mmHg} \quad P_2 = ??$$

$$T_1 = 18^\circ C = 291 K \quad T_2 = 32^\circ C = 305 K$$

$$\ln \frac{401}{P_2} = \frac{28000 \text{ J/mol}}{8.314 \text{ J/K}\cdot\text{mol}} \left[\frac{291 K - 305 K}{(291 K)(305 K)} \right]$$

$$= -0.493$$

$$\frac{401}{P_2} = e^{-0.493} = 0.611$$

$$P_2 = 656 \text{ mmHg}$$

* we expect the vapor pressure to be greater at higher temperature.

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Q1 The vapor pressure of C_6H_6 at 40°C is 313 torr, and at 80°C is 512 torr. what is the normal Boiling Point for C_6H_6 ?

* 120°C

(Intermolecular Forces and Liquids and Solids)

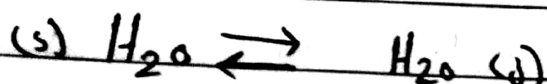
1. change of state.

2. Heating curve For water!!

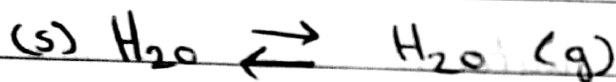
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(change of state)

Solid - Liquid Equilibrium



The melting point of a solid or the freezing point of a liquid is the temperature at which the solid and liquid phases coexist in equilibrium.



Molar heat of sublimation (ΔH) is the energy required to sublime 1 mole of a solid.

$$\Delta H_{\text{sub}} = \Delta H + \Delta H$$

$$= 6.01 \text{ kJ/mol} + 40.79 \text{ kJ/mol}$$

$$= 46.80 \text{ kJ/mol}$$

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The boiling point is the temperature at which the (equilibrium) vapor pressure of a liquid is equal to the external pressure.

The normal boiling point is the temperature at which a liquid boils when the external pressure is 1 atm.

(Temperature and Heat)

• when you add heat energy to an object, its temperature may increase

(Measuring Heat Energy)

• Since heat is energy, it can be measured in Joules.

• A common (and old-fashioned) unit of heat energy is the caloric.

(Specific Heat)

• The amount of heat energy required to 1g of an object to raise its temperature by 1°C is called specific heat.

$$\text{Specific heat} = \frac{q \text{ or } (\Delta H)}{\text{mass} \times \Delta T} = \frac{J}{g \cdot ^{\circ}\text{C}}$$

$$q \text{ or } (\Delta H) = \text{mass} \times \text{specific heat} \times \Delta T$$

(Specific Heat of water)

• By definition, the specific heat of water is $4.18 \text{ J/g} \cdot ^{\circ}\text{C}$.

• The specific heat of water, meaning one gram of water it takes 4.18 J of energy to raise the temperature of water 1°C (25°C to 26°C as an example)

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(Calculating Heat Energy)

• The amount of heat energy needed to raise the temperature of a substance depends on:

- The amount of the substance.
- The specific heat of the substance.
- The change in temperature.

$$q = mc \Delta T$$

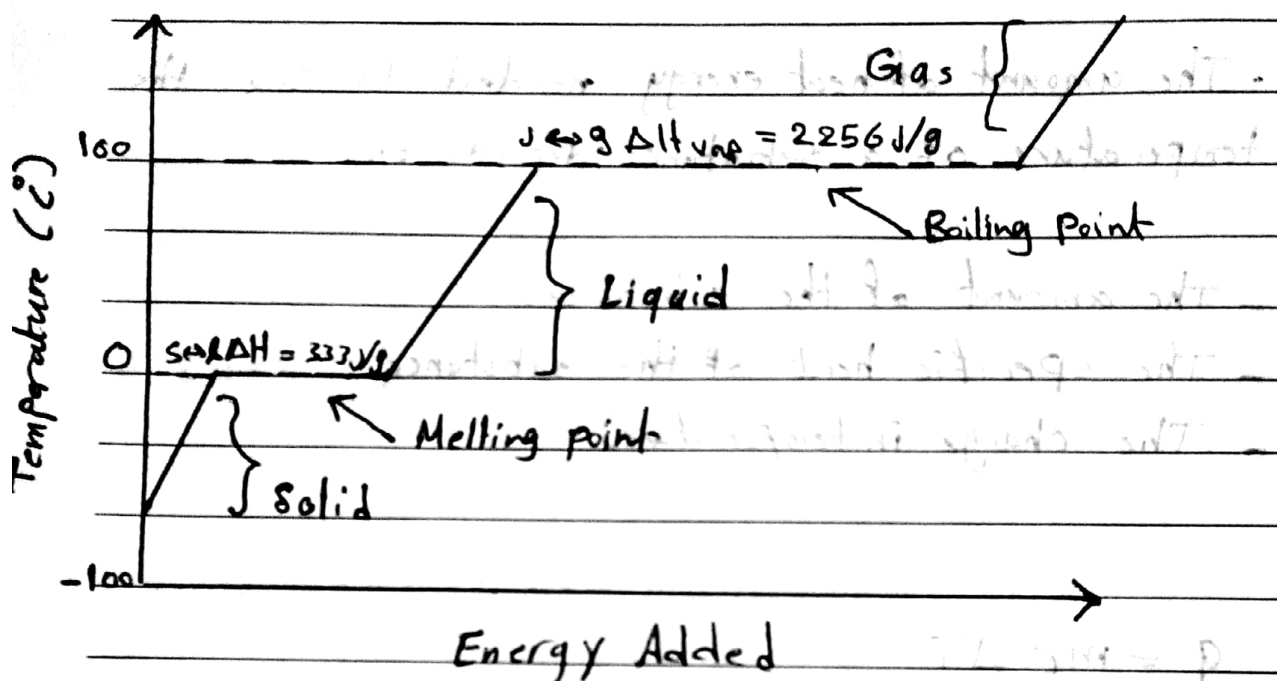
q : heat energy added / removed.

m : mass

c : specific heat

ΔT : change in temperature.

Heating curve of water



- Temperature change within phase
- depends on heat capacity of phase

$$c_{H_2O(l)} = 4.184 \text{ J/g}^\circ\text{C} \quad (\text{requires the most heat})$$

$$c_{H_2O(s)} = 2.077 \text{ J/g}^\circ\text{C}$$

$$c_{H_2O(g)} = 2.042 \text{ J/g}^\circ\text{C} \quad (\text{requires the least heat})$$

• Phase changes ($s \leftrightarrow l \leftrightarrow g$)

* temperature remains constant

* overcoming intermolecular forces

$$\Delta H_{m,} = 333 \text{ J/g} = 6.01 \text{ kJ/mol} \quad (s \leftrightarrow l)$$

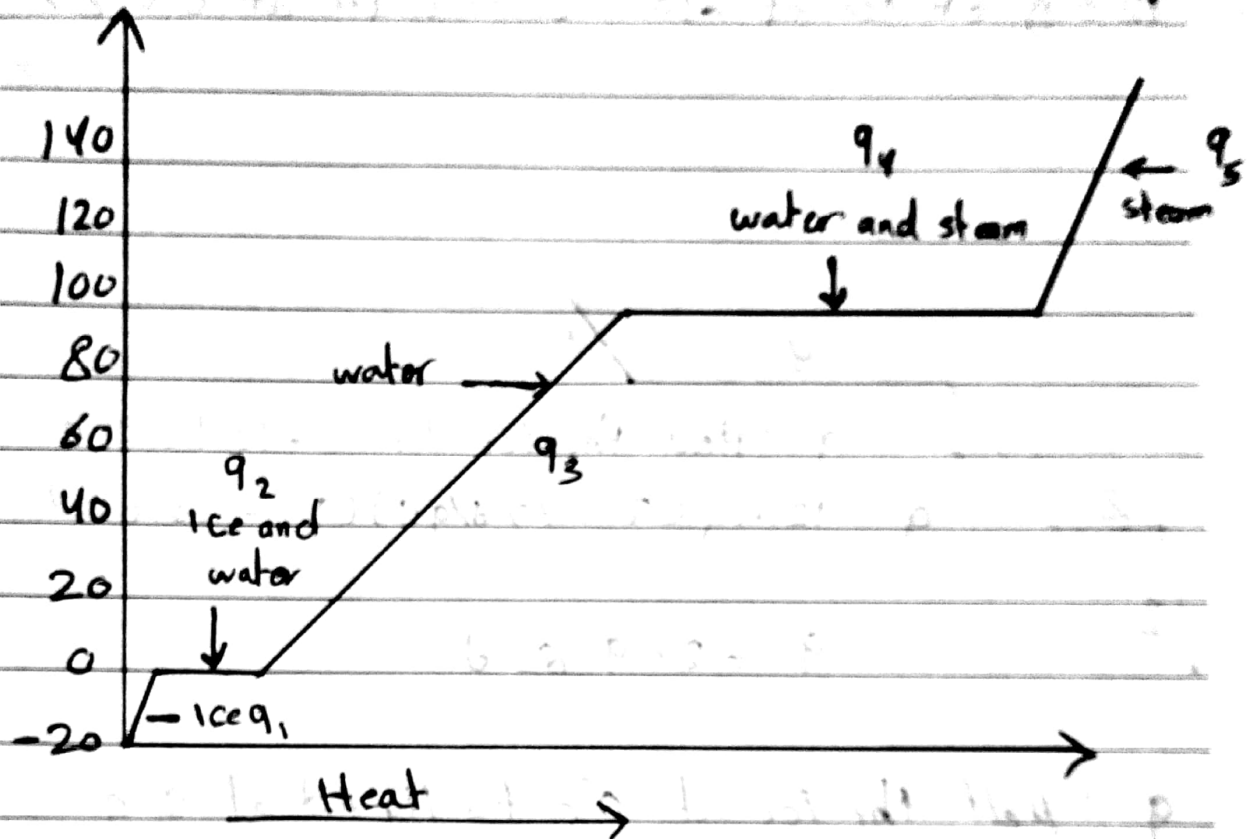
$$\Delta H_{v,} = 2256 \text{ J/g} = 40.79 \text{ kJ/mol} \quad (l \leftrightarrow g)$$

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Heating curve of water



q_1 : Heat the ice to 0°C

$$q_1 = m c_{\text{ice}} \Delta T$$

q_2 : Melt the ice into a liquid at 0°C

$$q_2 = m \Delta H_{\text{fus}}$$

q_3 : Heat the water from 0°C to 100°C

$$q_3 = m c_{\text{water}} \Delta T$$

q_4 : Boil the liquid into a gas at 100°C

$$q_4 = m \Delta H_{\text{vap}}$$

q_5 : Heat the gas above 100°C

$$q_5 = m c_{\text{steam}} \Delta T$$

$$Q = q_1 + q_2 + q_3 + q_4 + q_5$$

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1. How much energy (J) is required to heat 12.5 g of ice at -10.0°C to water at 0.0°C ?

4 / 5

3 q_1 : Heat the ice from -10 to 0°C

2 $q_1 = 12.5\text{g} (2.077\text{ J/g}^{\circ}\text{C}) (0.0 - -10.0^{\circ}\text{C})$

1 $q_1 = 259.63\text{ J}$

q_2 : Melt the ice at 0°C to liquid at 0°C

$$q_2 = 12.5\text{g} (333\text{ J/g})$$

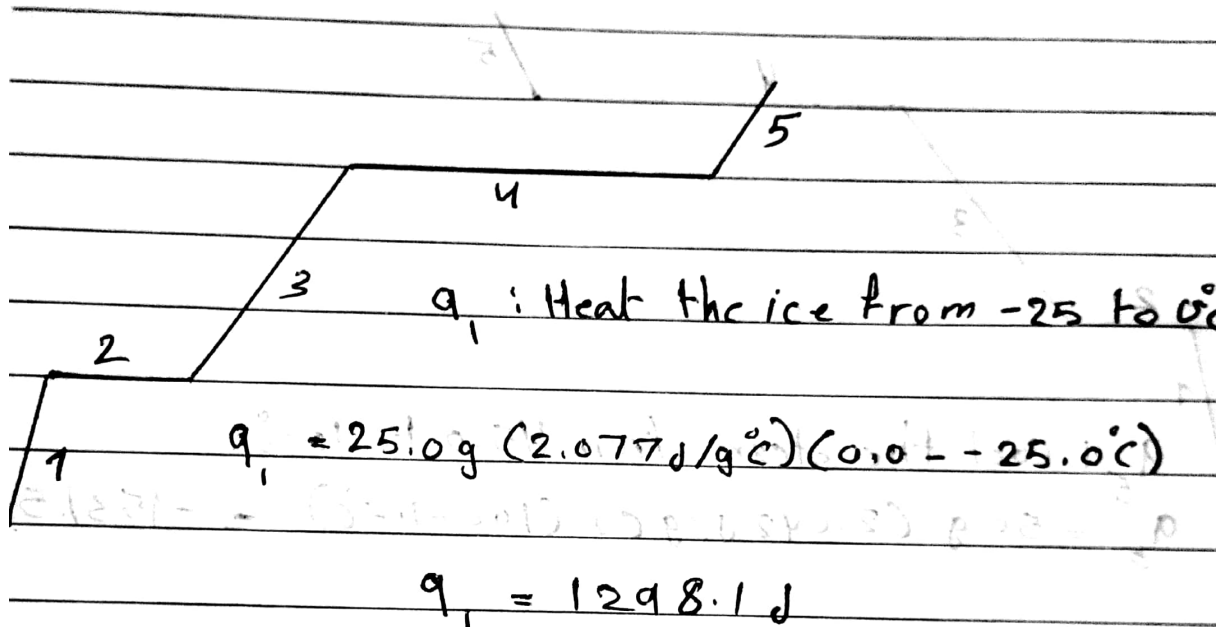
$$q_2 = 4162.5\text{ J}$$

$$q = q_1 + q_2$$

$$= 259.63\text{ J} + 4162.5\text{ J}$$

$$q = 4422\text{ J}$$

2. How much energy (q) is required to heat 25.0 g of ice at -25.0°C to water at 95.0°C ?



q_2 : Melt the ice at 0°C to liquid at 0°C

$$q_2 = 25.0 \text{ g} (333 \text{ J/g})$$

$$q_2 = 8325 \text{ J}$$

q_3 : Heat the water from 0°C to 95°C

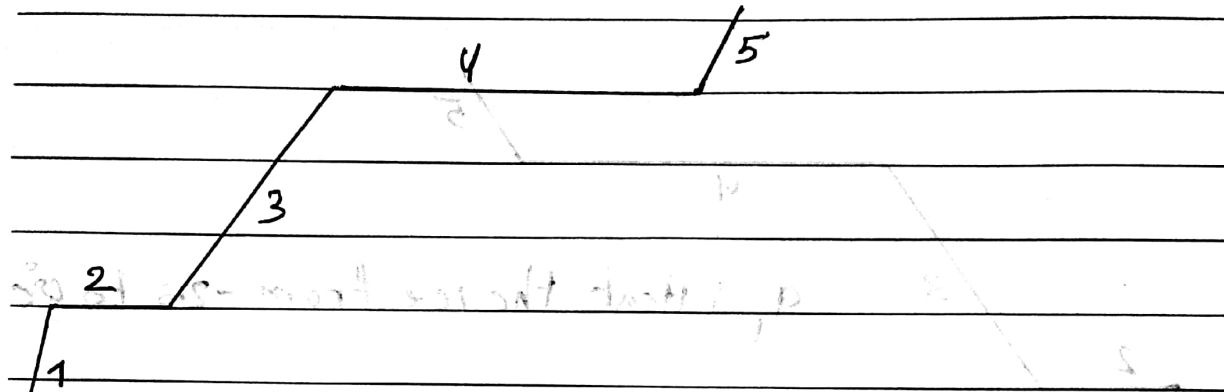
$$q_3 = 25.0 \text{ g} (4.184 \text{ J/g}^{\circ}\text{C}) (95.0 - 0.0^{\circ}\text{C})$$

$$q_3 = 9937 \text{ J}$$

$q = q_1 + q_2 + q_3$

$$1298.1 + 8325 + 9937 = 19560 \text{ J}$$

3. How much energy (J) is removed to cool 50 g of steam at 115 °C to ice at -5.0 °C?



q_1 : Cool the steam from 115.0 to 100 °C

$$q_1 = 50 \text{ g} (2.042 \text{ J/g}^\circ\text{C}) (100 - 115^\circ\text{C}) = -1531.5 \text{ J}$$

q_2 : Condense the steam into liquid at 100 °C

$$q_2 = 50 \text{ g} (-2256 \text{ J/g}) = -112800 \text{ J}$$

q_3 : Cool the water from 100 °C to 0 °C

$$q_3 = 50 \text{ g} (4.184 \text{ J/g}^\circ\text{C}) (0 - 100^\circ\text{C}) = -20920 \text{ J}$$

q_4 : Freeze the water into ice at 0 °C

$$q_4 = 50 \text{ g} (-333 \text{ J/g}) = -16650 \text{ J}$$

$$q_5 = 50 \text{ g} (2.077 \text{ J/g}^\circ\text{C}) (-5 - 0^\circ\text{C}) = -519.25 \text{ J}$$

$$q = q_1 + q_2 + q_3 + q_4 + q_5 = -152,000 \text{ J}$$

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physical properties of solutions

الخصائص الفيزيائية للحلول

A solution is a homogenous mixture of 2 or more substances (2g of NaCl in 100 g H₂O)

The solute is (are) the substance (s) present in the smaller amount (s) (2g NaCl)

The solvent is the substance present in the larger amount (100g H₂O)

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$\text{Mass (weight) percent} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

$$\text{Mole Fraction (X)}_A = \frac{\text{moles A}}{\text{total moles of solution}}$$

$$\text{Molality (m)} = \frac{\text{moles of solute}}{\text{Kilogram of solvent}}$$

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$\text{Molarity (M)} = \frac{\frac{\text{mass of solute}}{\text{Molar mass of solute}}}{\text{liters of solution}}$$

Q1 you have 1.00 mol of sugar in 125.0 mL of solution. Calculate the concentration in units of molarity.

* 8.00 M

Q1 you have a 10.0 M sugar solution. what volume of this solution do you need to have 2.00 mol of sugar?

* 0.200 L

Mass Percent

$$\text{Mass (weight) percent} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

$$\text{Weight \% of A} = \frac{\text{mass}_A}{\text{mass}_A + \text{mass}_B + \text{mass}_C + \dots} \times 100\%$$

Q1 what is the percent - by - mass concentration of glucose in a solution made by dissolving 5.5 g of glucose in 78.2 g of water?

* 6.6 %

Mole Fraction

$$\text{Mole Fraction } (X_A) = \frac{\text{moles A}}{\text{total moles of solution}}$$

$$\text{Mole Fraction } (X_A) = \frac{n_A}{n_A + n_u + n_c + \dots}$$

$$\text{Mole Fraction } (X) = \frac{\text{amount (mol) of solute}}{\text{amount (mol) of solute} + \text{amount (mol) of Solvent}}$$

Q1 A sample of rubbing alcohol contains 1.42g of isopropyl alcohol (C_3H_7OH) and 58.0g of water. what are the mole fractions of alcohol and water?

$$\text{moles isopropyl alcohol} = 1.42 \text{ g} \times \frac{1 \text{ mole}}{60.09 \text{ g}}$$

$$= 2.36 \text{ mol } C_3H_7OH$$

$$\text{moles water} = 58.0 \text{ g} \times \frac{1 \text{ mole}}{18.02 \text{ g}} = 3.22 \text{ mol } H_2O$$

$$X_{C_3H_7OH} = \frac{2.36 \text{ mol } C_3H_7OH}{2.36 \text{ mol } C_3H_7OH + 3.22 \text{ mol } H_2O} = 0.423$$

$$X_{H_2O} = \frac{3.22 \text{ mol } H_2O}{2.36 \text{ mol } C_3H_7OH + 3.22 \text{ mol } H_2O} = 0.577$$

Q1 A solution of phosphoric acid was made by dissolving 8.00 g of H_3PO_4 (M.M = 98 g/mol) in 100.0 mL of water (M.M = 18 g/mol). Calculate the mole fractions of H_3PO_4 . (Assume water has a density of 1.00 g/mL).

* 0.0145

Molality

$$\text{Molality (m)} = \frac{\text{moles of solute}}{\text{kilogram of solvent}}$$

$$\text{Molality (m)} = \frac{\text{mass of solute}}{\text{molar mass of solute} \times \text{kilogram of solvent}}$$

Q1) A solution of phosphoric acid was made by dissolving 8.00 g of H_3PO_4 (M.M = 98g/mol) in 100.0 ml of water. Calculate the molarity of the solution. (Assume water has a density of 1.00 g/ml).

* 0.816 M

Component 1	Component 2	state of resulting solution	Examples
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Gas	Gas	Gas	Air
Gas	Liquid	Liquid	soda water
Solid	Liquid	Liquid	NaCl in water

Q1 A sample of rubbing alcohol contains 142 g of isopropyl alcohol (C_3H_7OH) and 58.0 g of water. what are the mole fractions of alcohol and water?

*

$$\text{moles isopropyl alcohol} = 142 \text{ g} \times \frac{1 \text{ mole}}{60.09 \text{ g}}$$

$$= 2.36 \text{ mol } C_3H_7OH$$

$$\text{moles water} = 58.0 \text{ g} \times \frac{1 \text{ mole}}{18.02 \text{ g}} = 3.22 \text{ mol } H_2O$$

X

$$= \frac{2.36 \text{ mol } C_3H_7OH}{2.36 \text{ mol } C_3H_7OH + 3.22 \text{ mol } H_2O}$$

C_3H_7OH

$$= 0.423$$

X

$$= \frac{3.22 \text{ mol } H_2O}{2.36 \text{ mol } C_3H_7OH + 3.22 \text{ mol } H_2O}$$

H_2O

$$= 0.577$$

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Q1 what is the molality of a 5.86 M ethanol (C_2H_5OH) solution whose density is 0.927 g/ml?

$$* m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} \quad M = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Assume 1 L of solution:

5.86 moles ethanol = 270 g ethanol

927 g of solution (1000 ml $\times$ 0.927 g/ml)

$$\begin{aligned} \text{mass of solvent} &= \text{mass of solution} - \text{mass of solute} \\ &= 927 \text{ g} - 270 \text{ g} = 657 \text{ g} = 0.657 \text{ kg} \end{aligned}$$

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{5.86 \text{ moles } C_2H_5OH}{0.657 \text{ kg solvent}}$$

$$= 8.92 \text{ m}$$

Q1 Hydrogen peroxide is a powerful oxidizing agent used in concentrated solution as rocket fuels and in dilute solution as a hair bleach. An aqueous solution of H_2O_2 is 30.0% by mass and has a density of 1.11 g/mL. Calculate its

(a) Molality

(b) Mole fraction of H_2O_2

(c) Molarity

Sol

(a) From mass % to molality

$$g \text{ of } H_2O = 100 g \text{ solution} - 30.0 g H_2O_2$$

$$H_2O = 70.0 g H_2O$$

$$30.0 g H_2O_2 \times \frac{1 \text{ mol } H_2O_2}{34.02 g H_2O_2} = 0.882 \text{ mol } H_2O_2$$

$$\text{molality} = \frac{0.882 \text{ mol } H_2O_2}{70.0 g \times \frac{1 \text{ Kg}}{10^3 g}} = 12.6 m H_2O_2$$

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(b) From mass % to mole fraction:

$$70.0 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = 3.88 \text{ mol H}_2\text{O}$$

$$X_{\text{H}_2\text{O}_2} = \frac{0.882 \text{ mol H}_2\text{O}_2}{3.88 \text{ mol H}_2\text{O} + 0.882 \text{ mol H}_2\text{O}_2} = 0.185$$

(c) From mass % and density to molarity:

$$\text{volume (mL) of solution} = 100 \text{ g} \times \frac{1 \text{ mL}}{1.11 \text{ g}} = 90.1 \text{ mL}$$

$$\text{molarity} = \frac{\text{mol H}_2\text{O}_2}{\text{L soln}} = \frac{0.882 \text{ mol H}_2\text{O}_2}{90.1 \text{ mL} \times \frac{1 \text{ L soln}}{10^3 \text{ mL}}}$$

$$= 9.79 \text{ M H}_2\text{O}_2$$

* Colligative Properties

properties of solutions which depend on the number of solute particles in the solution and not the nature of the solute.

* Four Colligative Properties

- 1) Vapor pressure lowering. قلل المادّة اللّـسّـيـتـون
قلل حد القطر
- 2) Boiling point elevation. قلل اللّـسّـيـتـون مـزيجـه الـمـوجـود بالـعـيـن
- 3) Freezing point depression.
- 4) Osmosis

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* Vapor Pressure Lowering

the vapor pressure of the solution is lowered the solute particles at the liquid / vapor boundary block the solvent particle from jumping into vapor state.

$$P_{\text{sol}} = X_{\text{sol X}} P^{\circ}_{\text{sol X}}$$

or

$$\Delta P_{\text{sol X}} = X_{\text{solute}} P^{\circ}_{\text{sol X}}$$

Q1 Find the vapor pressure solution in (torr) P_s when 10.0 ml of glycerol ($C_3H_8O_3$) is added to 500 ml of water at $50^\circ C$. At this temperature, the vapor pressure of pure water is 92.5 torr and its density is 1.00 g/ml. The density of glycerol is 1.26 g/ml.

$$* 10.0 \text{ ml } C_3H_8O_3 \times \frac{1.26 \text{ g } C_3H_8O_3}{1 \text{ ml } C_3H_8O_3} \times \frac{1 \text{ mol } C_3H_8O_3}{92.09 \text{ g } C_3H_8O_3}$$

$$= 0.137 \text{ mol } C_3H_8O_3$$

$$500.0 \text{ ml } H_2O \times \frac{1.00 \text{ g } H_2O}{1 \text{ ml } H_2O} \times \frac{1 \text{ mol } H_2O}{18.0 \text{ g } H_2O}$$

$$= 27.8 \text{ mol } H_2O$$

$$\% \text{ } H_2O = \frac{27.8 \text{ mol } H_2O}{0.137 \text{ mol } C_3H_8O_3 + 27.8 \text{ mol } H_2O} = 0.995$$

$$p = 0.995 \times 92.5 \text{ torr} = 92.04 \text{ torr}$$

$$\Delta p = 92.5 - 92.04 = 0.46 \text{ torr}$$

vapor pressure lowering.

* Boiling Point Elevation

For nonvolatile, nonelectrolyte solvents the change in boiling point (ΔT_{bp}) is:

$$\Delta T_{bp} = K_{bp} m_{\text{solute}}$$

K_{bp} : boiling point elevation constant.

m_{solute} : molality of solute.

Q1 A solution was prepared by dissolving 25.00 g glucose in 200.0 g water. The molar mass of glucose is 180.16 g/mol. What is the boiling point of the resulting solution (in °C)? Glucose is a molecular solid that is present as individual molecules in solution.

* 100.35 °C

Q1 A solution was prepared by dissolving 25.00 g glucose in 200.0 g water. The molar mass of glucose is 180.16 g/mol. what is the boiling point of the resulting solution (in °C)? Glucose is a molecular solid that is present as individual molecules in solution,

$$T_b = 100^\circ\text{C}$$

$$\Delta T_b = K_b m \quad K_b \text{ water} = 0.51^\circ\text{C}/m$$

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{25\text{ g} \times \frac{1\text{ mol}}{180.16\text{ g}}}{0.200\text{ kg solvent}} = 0.69\text{ m}$$

$$\Delta T_b = K_b m = 0.51^\circ\text{C}/m \times 0.69\text{ m} = 0.35^\circ\text{C}$$

$$\Delta T_b = T_b - T_b^\circ$$

$$T_b = T_b^\circ + \Delta T_b = 100^\circ\text{C} + 0.35^\circ\text{C} = 100.35^\circ\text{C}$$

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* Freezing Point Depression

For nonvolatile, nonelectrolyte solvents the change in freezing point (ΔT_{fp}) is:

$$\Delta T_{fp} = K_{fp} m_{\text{solute}}$$

K_{fp} : Freezing point depression constant.

m_{solute} : molality of solute.

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Q1 what is the freezing point of a solution containing 478 g of ethylene glycol (antifreeze) in 3202 g of water? The molar mass of ethylene glycol is 62.01 g

$$\Delta T_f = K_f m$$

$$K_f, \text{water} = 1.86^\circ\text{C}/m$$

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{478 \text{ g} \times \frac{1 \text{ mol}}{62.01 \text{ g}}}{3.202 \text{ kg solvent}}$$

$$= 2.41 m$$

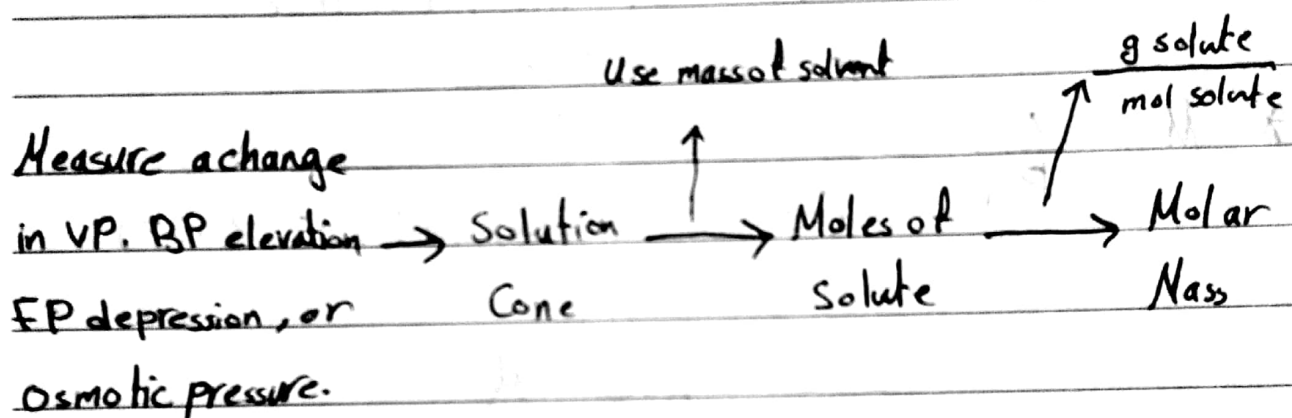
$$\Delta T_f = K_f m = 1.86^\circ\text{C}/m \times 2.41 m = 4.48^\circ\text{C}$$

$$\Delta T_f = T_f^\circ - T_f$$

$$T_f = T_f^\circ - \Delta T_f = 0.00^\circ\text{C} - 4.48^\circ\text{C} = -4.48^\circ\text{C}$$

* Colligative Properties and Molar Mass Determination

Colligative Properties can be used to determine the molar mass of a solute when it is dissolved in a solvent of appreciable vapor pressure and a known k_{bp} or k_{fp} .



* Osmosis and Osmotic Pressure.

The pressure created by a column of solution for a system in equilibrium.

$$PV = nRT$$

$$P = MRT$$

$$\pi = MRT$$

π : Osmotic pressure

M : molar conc (mol/L)

R : 0.08206 $\frac{\text{L atm}}{\text{mol K}}$

T : Temperature (K)

* انتقال الماء من المحلول
الأقل إلى الأكثر تركيز

Q1 Biochemists have discovered more than 400 mutant varieties of hemoglobin, the blood protein that carries O_2 . A physician dissolves 21.5 mg of one variety in water to make 1.50 mL of solution at $5.0^\circ C$. measures an osmotic pressure of 3.61 torr. what is the molar mass of the protein?

$$* M = \frac{\pi}{RT} = \frac{3.61 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}}}{(0.0821 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K}) (278.15 \text{ K})}$$

$$= 2.08 \times 10^{-4} \text{ M}$$

$$M = \text{mole} / V (\text{solution}) \rightarrow \text{mol} = M \times V$$

$$\frac{2.08 \times 10^{-4} \text{ mol}}{1 \text{ L}} \times 0.00150 \text{ L} = 3.12 \times 10^{-7} \text{ mol}$$

$$21.5 \text{ mg} \times \frac{1 \text{ g}}{10^3 \text{ mg}} = 0.0215 \text{ g}$$

$$\mathcal{M} = \text{mass} / \text{mol} = \frac{0.0215 \text{ g}}{3.12 \times 10^{-7} \text{ mol}} = 6.89 \times 10^4 \text{ g/mol}$$

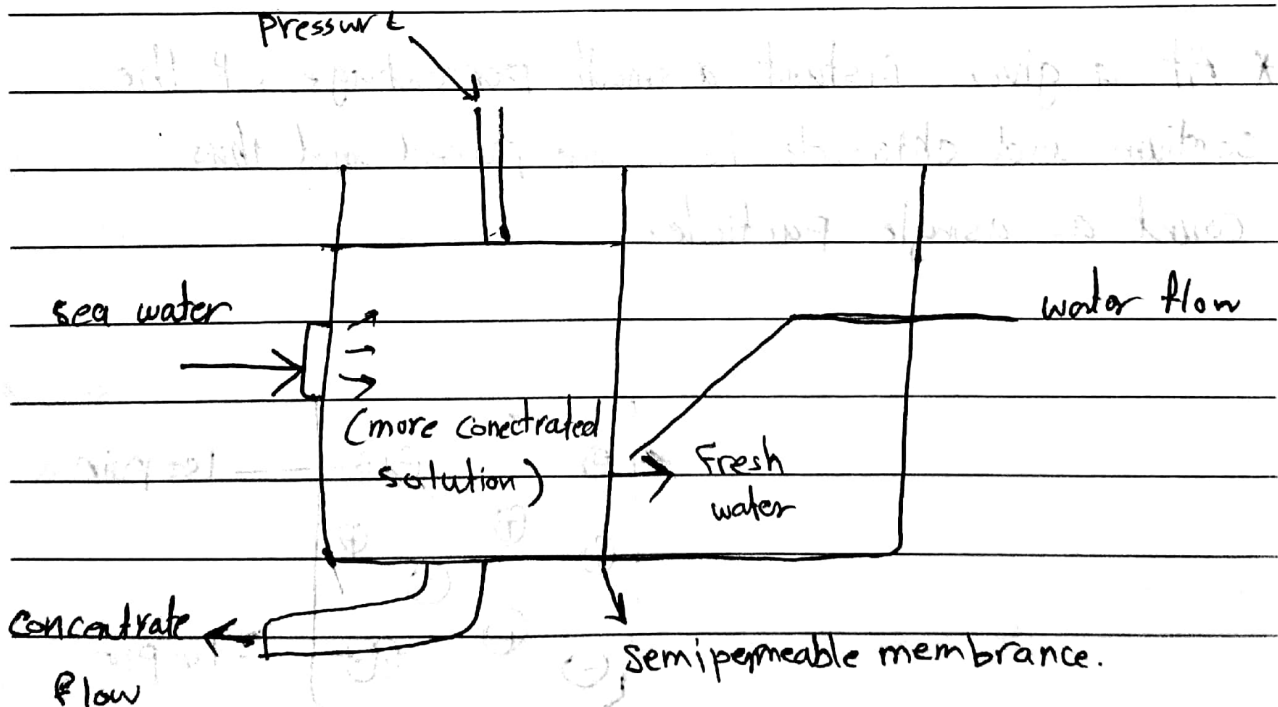
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Q1 when 33.4 mg of a compound is dissolved in 10.0 ml of water at 25°C the solution has an osmotic pressure of 558 torr. calculate the molar mass of this compound.

* 111 g/mol

Reverse Osmosis is used for water purification

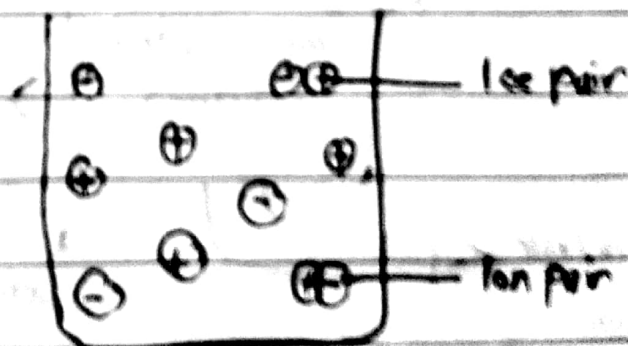


* The relationship between the moles of solute dissolved and the moles of particles in solution is usually expressed as:

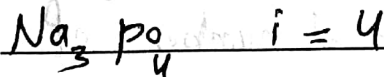
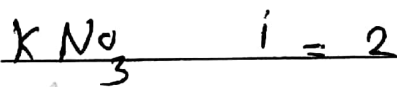
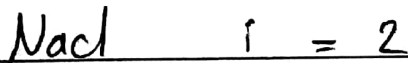
$$i = \frac{\text{moles of particles in solution}}{\text{moles of solute dissolved}}$$

Ion pairing

* At a given instant a small percentage of the sodium and chloride ions are paired and thus count as a single particle.



* The expected value for i can be determined for a salt by noting the number of ions per formula unit (assuming complete dissociation and that ion pairing does not occur).



* Ion pairing is most important in concentrated solutions.

* As the solution becomes more dilute, the ions are farther apart and less ion pairing occurs.

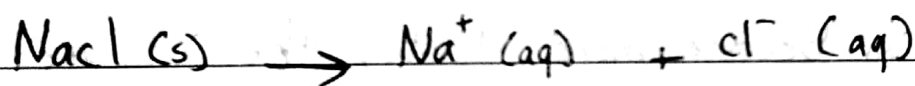
* Ion pairing occurs to some extent in all electrolyte solutions.

* Ion pairing is most important for highly charged ions.

Colligative Properties of Solutions Containing Ions

* The change in VP, BP, FP, osmotic Pressure is greater than expected for electrolyte (ionic salt) solutions.

* Colligative Properties depend on the total number of solute particles in solution, ionic compounds form ions in solution so the total number of solute particles in solution is equal to the total ions in solution.



0.100 m

0.100 m

0.100 m

0.200 m total

$$\Delta T_{bp} = i K_{bp} m$$

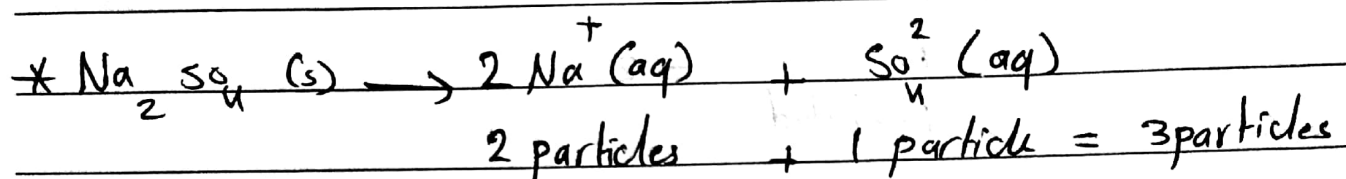
$$\Delta T_{fp} = i K_{fp} m$$

$$\pi = i M R T$$

$$P_{\text{solvent}} = 1 \times P^{\circ}_{\text{solvent}}$$

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Q1 Find the vapor pressure solution in (torr) p, when 35.0 g of solid Na_2SO_4 (M.M = 142 g/mol) is added to 175 g of water at 25°C . At this temperature the vapor pressure of pure water is 23.76 torr.



$i_{\text{predicted}} = 3$

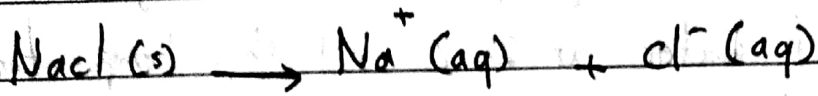
$$35.0 \text{ g Na}_2\text{SO}_4 \times \frac{1 \text{ mol Na}_2\text{SO}_4}{142 \text{ g Na}_2\text{SO}_4} = 0.246 \text{ mol Na}_2\text{SO}_4$$

$$175.0 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.00 \text{ g H}_2\text{O}} = 9.72 \text{ mol H}_2\text{O}$$

$$\%_{\text{H}_2\text{O}} = \frac{9.72 \text{ mol H}_2\text{O}}{3(0.246 \text{ mol Na}_2\text{SO}_4) + 9.72 \text{ mol H}_2\text{O}} = 0.929$$

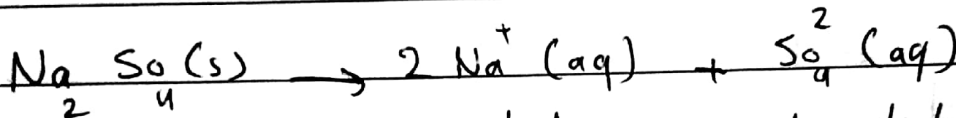
$$p = 0.929 \times 23.76 \text{ torr} = 22.07 \text{ torr}$$

Predicting van't Hoff Factors



1 particle + 1 particle = 2 particles

$i_{\text{predicted}} = 2$



2 particles + 1 particles = 3 particles

$i_{\text{predicted}} = 3$

which solution have higher boiling point elevation 0.2 m NaCl or 0.2 m $\text{Na}_2\text{SO}_4 (\text{s})$

$i_{\text{predicted}} = 2$

$i_{\text{predicted}} = 3$

$$\Delta T_{\text{bp}} = i K_{\text{bp}} m$$

$$\Delta T_{\text{bp}} = i K_{\text{bp}} m = 2 K_{\text{bp}} 0.2 = 0.4 K_{\text{bp}}$$

$$\Delta T_{\text{bp}} = i K_{\text{bp}} m = 3 K_{\text{bp}} 0.2 = 0.6 K_{\text{bp}}$$

$$\frac{C}{6} \frac{H}{12} \frac{O}{6} = 5\%$$

A red blood cell in an isotonic solution has its normal shape.

$$\frac{C}{6} \frac{H}{12} \frac{O}{6} = 3\%$$

A hypotonic solution has a lower concentration of particles than the cell. A cell in a hypotonic solution absorbs water and swells until it bursts.

$$\frac{C}{6} \frac{H}{12} \frac{O}{6} = 15\%$$

A hypertonic solution has a higher concentration of dissolved particles than the cell. If a cell is placed in a hypertonic solution, water moves out of the cell, causing it to shrink.