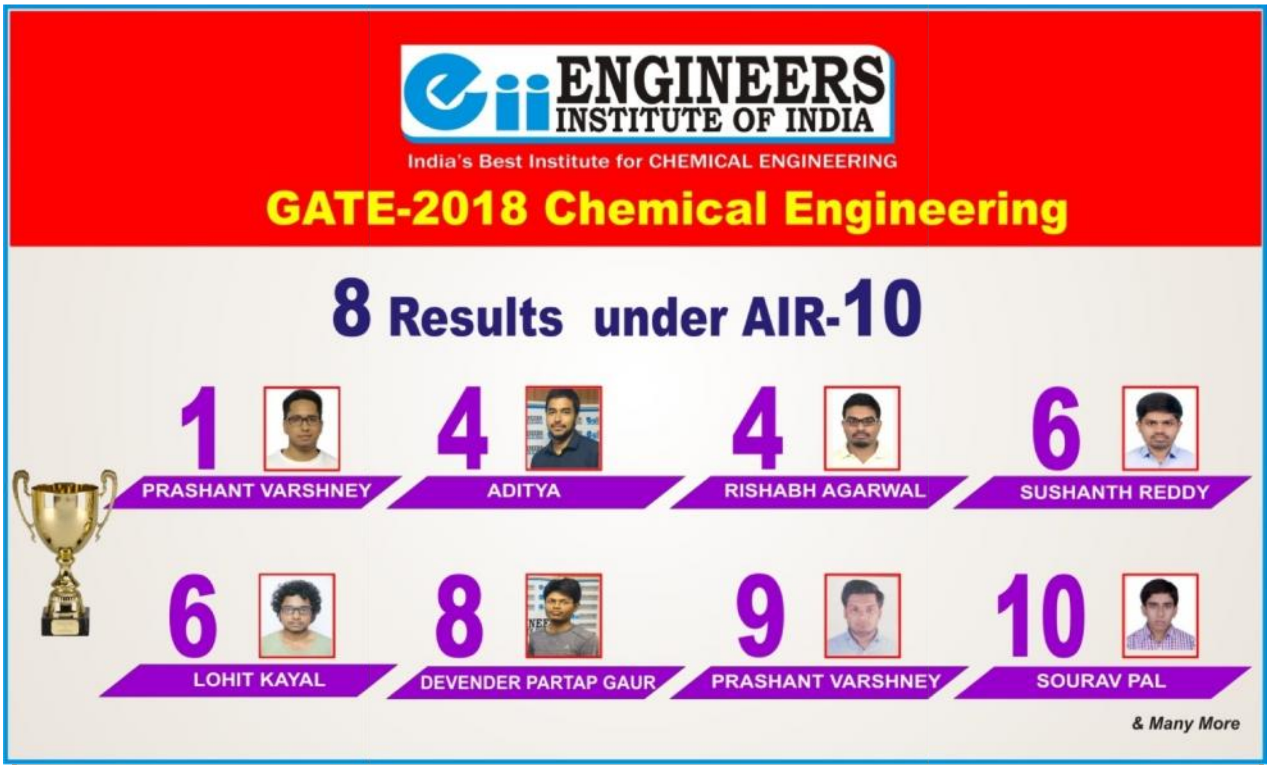

Postal Correspondence

GATE & PSUs

CHEMICAL ENGINEERING

PROCESS CALCULATIONS

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GATE-2019 Syllabus: Chemical Engineering - CH

Process Calculations: Laws of conservation of mass and energy ; use of tie components; recycle, bypass and purge calculations.

(Conversion, Material Balance with and without chemical reaction, Combustion, Crystallisation, Humidification & Energy Balance)

CONTENT

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CHAPTER-1

INTRODUCTION

Units & Dimensions

(1.) **Newton (N):** The SI unit of force. It is equal to the force that would give a mass of one kilogram an acceleration of one m/s^2, and is equivalent to 100,000 dynes.
Metric unit of force, used also as a unit of weight (force due to gravity).

1 Newton = 1 kg • m/s^2
The definition of the standard metric unit of force is stated by the above equation. One Newton is defined as the amount of force required to give a 1-kg mass an acceleration of 1 m/s^2.

(2.) **Kilogram-force (kg_f)**: The **kilogram-force** is a metric unit of force (*kgf*). The kilogram-force is equal to a mass of one kilogram multiplied by the standard acceleration due to gravity on Earth, which is defined as exactly 9.80665 meter per second². Then one (1) kilogram-force is equal to 1 kg × 9.80665 meter per second² = 9.80665 kilogram × meter per second² = 9.80665 newton (1N).
Note : A kilogram-force (kgf), also called kilopond (kp), is a gravitational metric unit of force.

(3.) **Mole: Mole** is a unit of measurement used in **chemistry** to express amounts of a **chemical** substance, defined as the amount of any substance that contains as many elementary entities as there are atoms in 12 grams of pure carbon-12, the isotope of carbon with relative atomic mass of exactly 12 by definition.

In other words a **mole** is simply a unit of measurement. Units are invented when existing units are inadequate. Chemical reactions often take place at levels where using grams wouldn't make sense, yet using absolute numbers of atoms/molecules/ions would be confusing, too.

A mole is the quantity of anything that has the same number of particles found in 12.000 grams of carbon-12. That number of particles is Avogadro's Number, which is roughly $6.02 x 10^{23}$. A mole of carbon atoms is 6.02×10^{23} carbon atoms. A mole of chemistry teachers is $6.02 x 10^{23}$ chemistry teachers.

Examples: 1 mole of NH_3 has 6.022×10^{23} molecules and weighs about 17 grams. 1 mole of copper has 6.022×10^{23} atoms and weighs about 63.54 grams.

Mole = $\dfrac{\text{mass in gram}}{\text{molecular weight}}$

(4.) **Avogadro's number:** Avogadro's number is the number of particles found in one mole of a substance. It is the number of atoms in exactly 12 grams of carbon-12. This experimentally determined value is approximately 6.022×10^{23} particles per mole. Also known as Avogadro's constant

$$\boxed{1\text{mol} = 6.023 \times 10^{23} \text{atoms}}$$

(5.) **Pressure:** The ratio of force to the area over which that force is distributed.
Pressure is force per unit area applied in a direction perpendicular to the surface of an object.

$$P = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} = \frac{F.d}{A.d} = \frac{W}{V} = \frac{\text{Energy}}{\text{Volume}}$$

(6.) **Gauge pressure:** The amount by which the pressure measured in a fluid exceeds that of the atmosphere. Gauge pressure is the pressure relative to atmospheric pressure. Gauge pressure is positive for pressures above atmospheric pressure, and negative for pressures below it.

$$\text{Absolute pressure} = \text{Gauge pressure} + \text{Atmospheric pressure}$$

(7.) **Absolute pressure** is zero-referenced against a perfect vacuum, so it is equal to gauge pressure plus atmospheric pressure.
A barometer is a device that measures atmospheric pressure.

(8.) **Vacuum pressure** - Pressures below atmospheric pressure are called vacuum pressures and are measured by vacuum gages that indicate the difference between the atmospheric pressure and the absolute pressure.

$$P_{gauge} = P_{absolute} - P_{atmospheric}$$

$$P_{vacuum} = P_{atmospheric} - P_{absolute}$$

$$P_{absolute} = P_{atmospheric} + P_{gauge}$$

(9.) **Molarity (M):** Molarity's definition is a unit of measurement used to denote the concentration of a particular substance or solution. Molarity is expressed as moles of solute over liters of solution. It is denoted either by a capital M or by the term molar.

$$\text{Molarity (M)} = \frac{\text{No. of gram moles of solute}}{\text{Volume of solution in Litre}}$$

(10.) **Normality**(N): Normality is a measure of concentration equal to the gram equivalent weight per liter of solution. Gram equivalent weight is the measure of the reactive capacity of a molecule.

$$\text{Normality (N)} = \frac{\text{Gram equivalent of solute}}{\text{Volume of solution in Litre}}$$

For acid reactions, a 1 M H_2SO_4 solution will have normality (N) of 2 N because 2 moles of H^+ ions are present per liter of solution. For sulfide precipitation reactions, where the SO_4^- ion is the important part, the same 1 M H_2SO_4 solution will have a normality of 1 N.

(11.) **Molality:** Molality is the number of moles of solute per kilogram of solvent. It is important the mass of solvent is used and not the mass of the solution. Solutions labeled with molal concentration are denoted with a lower case m.

$$\text{Molality (m)} = \frac{\text{No. of gram moles of solute}}{\text{Weight of solvent in Kilogram}}$$

The important part of remembering the difference is
Molarity - M → moles per liter solution
Molality - m → moles per kilogram solvent

(12.) **Concentration :** It is defined as the amount of solute in gram dissolved in one litre of solution. It is denoted by symbol 'C'

$$\text{Concentration (C)} = \frac{\text{Mass of solute in gram}}{\text{Volume of solution in litre}} = \text{Normality} \times \text{Equivalent weight}$$

(13.) **Equivalent weight:** The equivalent weight to an element or a compound is equal to the atomic weight or molecular weight divided by valence.

$$\text{Equivalent weight} = \frac{\text{Atomic weight or Molecular weight}}{\text{Valency}}$$

(14.) **Valency:** Valency of an element or compound depends on number of hydrogen ions accepted or the hydroxyl ions donated for each atomic weight or molecular weight.

(15.) **Work:** Work is defined as the product of the force acting on body and the distance travelled by the body in the direction of force applied.
The SI units for work are the joule (J) or Newton-meter (N * m), from the function W = F * s where W is work, F is force, and s is the displacement. The joule is also the SI unit of energy.

$$\text{Joule} = \text{N.m} = \frac{\text{kg. m}^2}{\text{s}^2}$$

(16.) **Power:** Power is the time rate at which work is done or energy is transferred. In calculus terms, power is the derivative of work with respect to time.
The SI unit of power is the watt (W) or joule per second (J/s). Horsepower is a unit of power in the British system of measurement.

Power = Work / time or **P = W / t**

Ideal gas Laws & their Applications

(17.) **Boyle's law:** Boyle's Law states that the product of the pressure and volume for a gas is a constant for a fixed amount of gas at a fixed temperature. Written in mathematical terms, this law is,

$$P \propto \frac{1}{V} \qquad P = \frac{C}{V} \qquad \boxed{PV = C}$$

Where P = Absolute pressure, C = constant
V = Volume occupied by gas P V = constant
If a sample of gas initially at pressure P_i and volume V_i is subjected to a change that does not change the amount of gas or the temperature, the final pressure P_f and volume V_f are related to the initial values by the equation $P_i V_i = P_f V_f$

Key Points

- According to Boyle's Law, if pressure doubles, volume halves.
- Boyle's Law holds true only if the number of molecules n and the temperature are both constant.
- Boyle's Law is used to predict the result of introducing a change, in volume and pressure only, to the initial state of a fixed quantity of gas.

Important Terms

Boyle's law

Boyle's law (sometimes referred to as the Boyle–Mariotte law) states that the absolute pressure and volume of a given mass of confined gas are inversely proportional, if the temperature remains unchanged within a closed system.

Ideal gas

An ideal gas is a theoretical gas composed of a set of randomly-moving, non-interacting point particles.

Isothermal

In thermodynamics, a curve on a p-V diagram for an isothermal process.

Boyle's law : Practice Questions

1. Boyle's Law states that...
   (a) P1V1 = P2V2
   (b) P1V2 = P2V1
   (c) P2V1 = P1V2
   (d) all of the above
2. Boyle's Law also states that...
   (a) at a constant temperature, the pressure exerted by a gas varies inversely with the volume of that gas.
   (b) at a constant temperature, the pressure exerted by a gas varies directly with the volume of that gas.
   (c) at a constant temperature, the pressure exerted by a gas remains the same no matter what the volume of that gas is.
   (d) at a constant temperature, the volume of a gas remains the same no matter what the pressure exerted by that gas is.
3. An application of Boyle's Law is...
   (a) at a constant temperature, as the pressure on a gas increases, the volume decreases.
   (b) at a constant temperature, as the volume of a gas increases, the pressure decreases.
   (c) at a constant temperature, as the pressure on a gas increases, the volume increases.
   (d) A and B.
4. As a volume of a gas increases, the number of molecules of that gas that collide with the walls of the container decreases.
   (a) True
   (b) False


Postal Course Program
This is well revised and updated as per latest syllabus and pattern of
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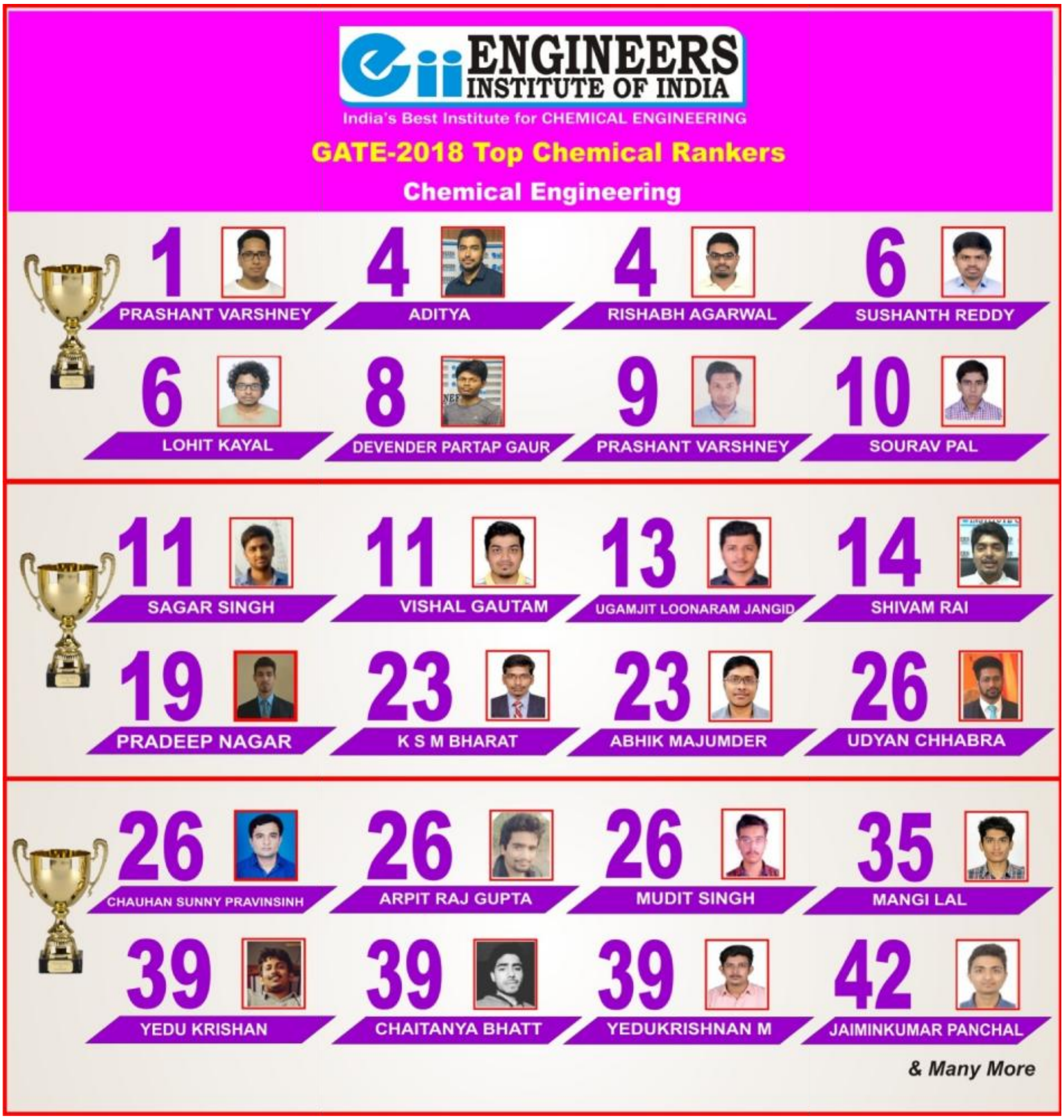
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