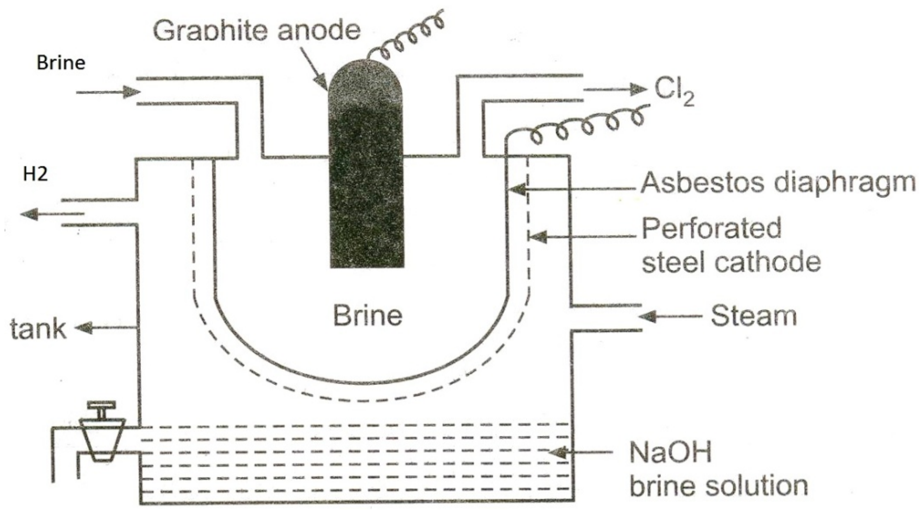
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given moreImportance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constantvalues may vary and there may be some difference in the candidate's answers and modelanswer.
6) In case of some questions credit may be given by judgement on part of examiner of relevantanswer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based onequivalent concept.

Q No.	Answer	Marks
1A	**Attempt any six**	
a)	**Raw material for sulfuric acid** Sulfur, air, water **Uses of sulfuric acid (any two)** a) For manufacturing of Fertilizers b) Oil refining c) Metal processing d) Manufacturing of Rayon e) In Lead acid batteries f) Detergent manufacturing	1 1
b)	**Reactions in sulfuric acid manufacturing** $S + O_2 = SO_2$ $SO_2 + ½ O_2 = SO_3$ $SO_3 + H_2O = H_2SO_4$	2
c)	SO_3 is dissolved in H_2SO_4 to form or fuming H_2SO_4. If SO_3 dissolved directly in water, then a large amount of heat is evolved. This heat gives a dense form of minute particles of H_2SO_4. These particles do not easily condense down.	2
d)	**Advantages of contact process** • Yield of sulfuric acid is more • Contact process can produce high concentrated sulfuric acid • It reduces emission of SO_2.	1 mark each for any two
e)	**Steel** is used as **MOC** in **sulfuric acid** plant to withstand high temperature and better corrosion resistance.	2
f)	**Le Chatelier's Principle states**: when a change is introduced to a system in	2

	equilibrium, the equilibrium shifts in the direction that relieves the change.	
g)	**Types of cement** 1) Portland cement 2) Pozzolanic cement 3) Natural cement 4) High alumina cement 5) Super sulphate cement 6) Quick setting cement	Any four (half mark each)
h)	**Properties of chlorine (any 2)** MW : 35, MP: – 101.5 ^oC, BP : -34.4 ^oC It is a greenish yellow pungent smelling gas and is poisonous in nature.It causes headache if inhaled in small quantities.It dissolves in water to give chlorine water.It can be easily liquefied. It oxidizes,bleaches,disinfects. **Properties of caustic soda (any 2)** MW : 40, BP : 1390^oC, MP : 318^oC, Very soluble in water with high exothermic heat of reaction.	1 1
1B	**Attempt any two**	
a)	**Diaphragm cell**	4

<table>
<tr><td></td><td>
</td><td></td></tr>
<tr><td>b)</td><td>Acetylene from CaC_2
Raw materials: lime stone, coke, water

Chemical reactions:

$CaO + 3C \rightarrow CaC_2 + CO$
$CaC_2 + H_2O \longrightarrow Ca(OH)_2 + CH \equiv CH$
$CaCO_3 \rightarrow CaO + CO_2$
$2CO + O_2 \rightarrow 2\,CO_2$
Process Description:
Calcium carbide is produced by heating lime and coke in an electric furnace at 2100 ˚C . Molten CaC_2 is solidified and cooled and ground under nitrogen
In the wet process the pulverized carbide is fed through a gas tight hopper to a C2H2 generator in which the quality of water used is sufficient to discharge $Ca(OH)_2$. The carbide is fed to water at a measured rate until exhausted.
Calcium hydroxide slurry containing 90% water is discharged. The gas is passes through a scrubber to remove impurities like NH_3, sulphides, phosgene and finally through a purifier containing iron oxide and alumina or silica gel. The temperature in the gas generator is kept below 90˚C and a pressure of 2 atm.</td><td>1

1</td></tr>
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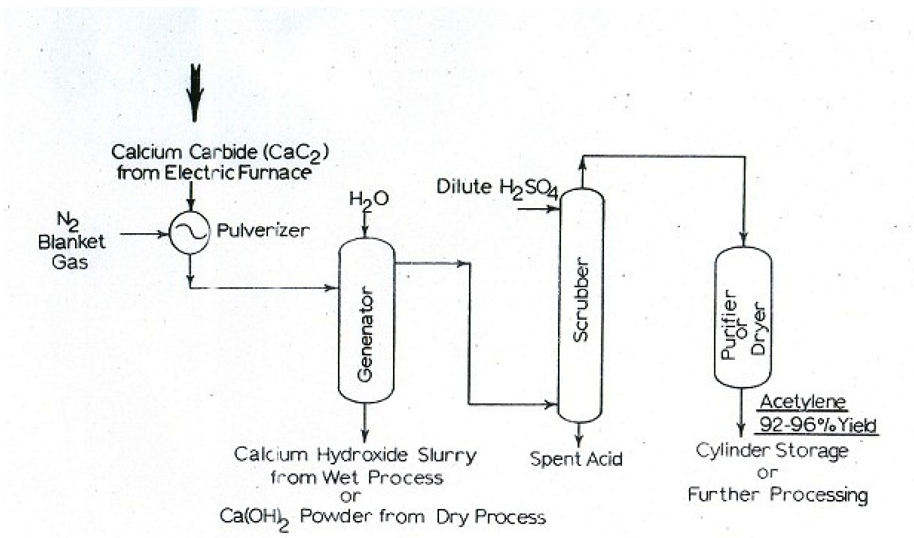
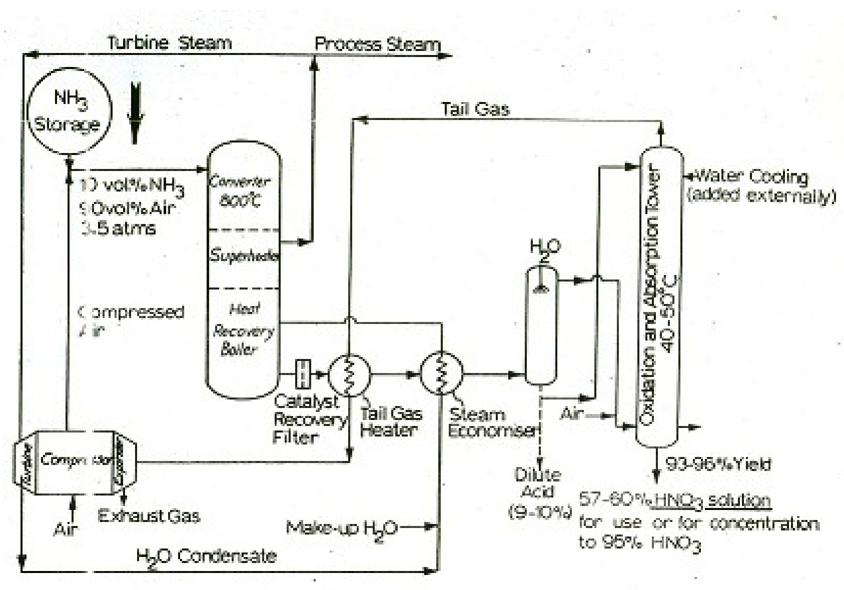
	In a dry process equal weights of the quantities H_2O and CaC_2 are used in the generator to eliminate waste disposal problem of lime slurry. The heat of reaction is largely dissipated by water vaporization leaving by product lime in dry state. The dry process is more dangerous because of the temperature control in the generator. Acetylene polymerizes at 250˚C and above and decomposes violently at 650˚C . Hence temperature is maintained below 150˚C and 30 cm of water pressure.  	2
c)	**Hardening of cement:**Hardening is a process of crystallization. Crystals form (after a certain length of time which is known as the initial set time) and interlock with each other. Concrete is completely fluid before the cement sets, and then progressively hardens. The cement and water mixture that has crystallized in this way encloses the aggregate particles and produces a dense material. The term **Setting**is used to describe the stiffening of the cement paste. Setting	2+2

	of cement refers to changes of cement paste from a fluid to rigid state. Setting differs from Hardening of cement.	
2	**Attempt any two**	**16**
a)	**Nitric Acid Production** Raw material Ammonia, air, water Reaction $4NH_3+5O_2 = 4NO + 6H_2O$ $2NO+O_2 = 2NO_2$ $3NO_2+H_2O=2HNO_3+NO$	2



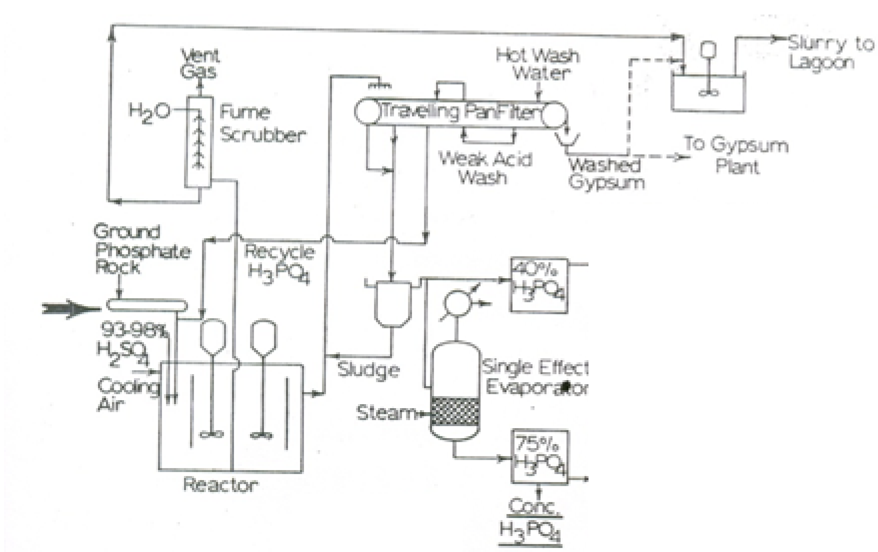
		3
	Ammonia and air are compressed and send to the catalytic converter. Ammonia is oxidized and converted into nitric oxide. Large heat is evolved which can de utilized to run turbine by producing steam and gas expander. Both are connected to the compressor. Hence compressor does not require external energy source. NOx gases after heat recovery is send through cooler	3

condenser where it is cooled by cooling tower water. Some part of acid is converted into liquid form. Both liquid and gas are send to absorption tower at different feed plates. Air is provided from the bottom to complete oxidation of NO. Water is fed from the top of the tower. Nitric acid (60%) is collected at the bottom. Tail gases from the absorber are used to run gas expander after heating.

b) **Phosphoric acid**

Reaction: 2

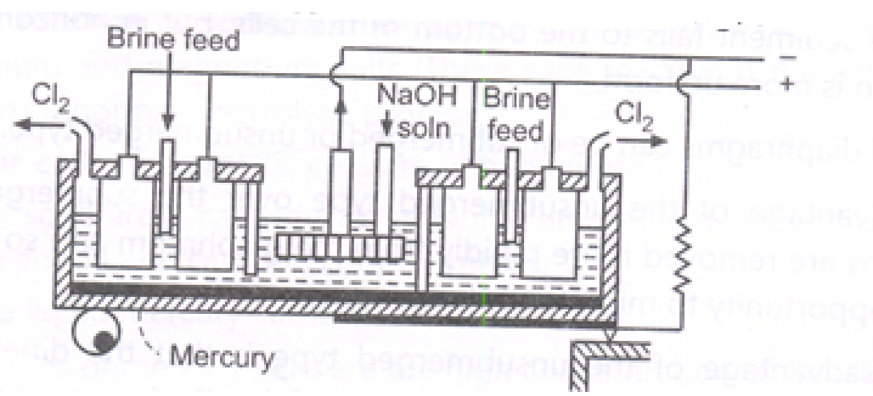
$Ca_3(PO_4)_2 + 3H_2SO_4 + 6H_2O = 2H_3PO_4 + 3(CaSO_4.2H_2O)$



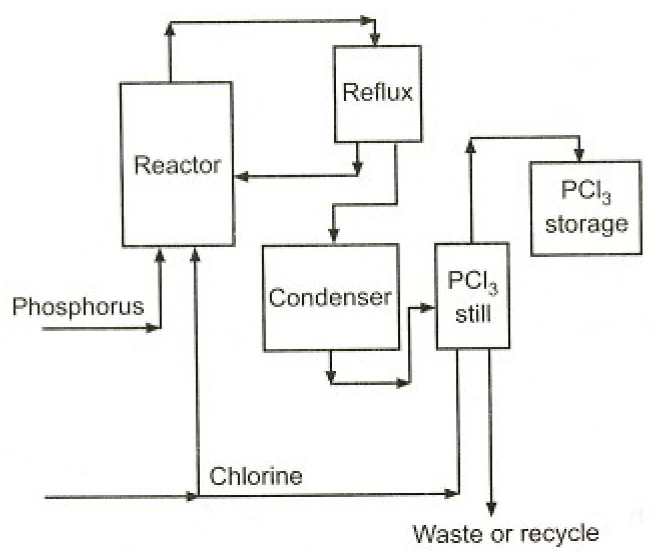
3

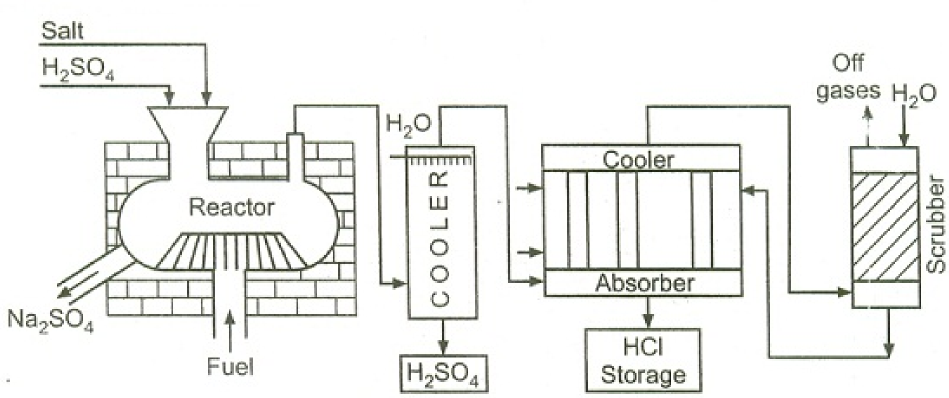
Process:

Phosphate rock is ground and fed to chute where a recycle stream of weak phosphoric acid washes into reaction tank. Strong sulfuric acid is fed to the reactor. Around 98% conversion takes in 4-6 hours. Heat of reaction is controlled by using cooling air. Gypsum –Acid slurry is fed to travelling pan filter where 40% acid is removed and cake is washed with water. Filtrate is return to the reactor. The gypsum obtained is dried and send for paint or 3

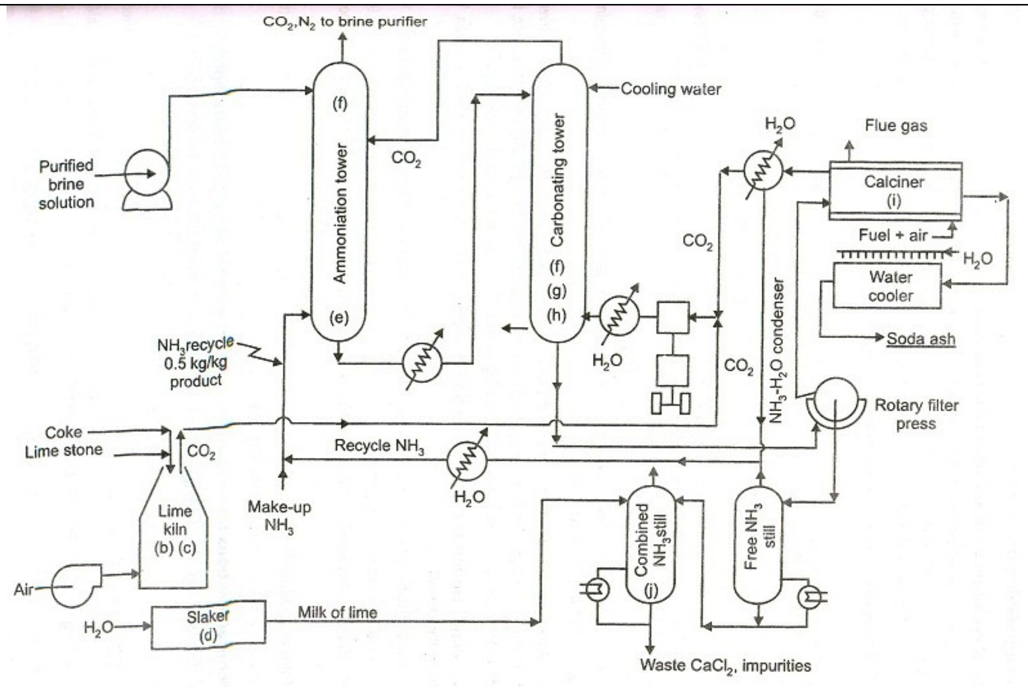
	cement manufacturing. Dilute acid obtained can be concentrated in single effect evaporator.	
c)	**Mercury Cell**  Mercury cell : Cell notation Anode: $\uparrow Cl_2 \mid C, NaCl(aq)$ Cathode: $Na^o \mid NaHg$ Cell reaction : Anode : $Cl^- - e^- \rightarrow \frac{1}{2} Cl_2$ Cathode : $Na^+ + e \rightarrow Na^o$ Denuding : $NaHg + H_2O \rightarrow NaOH + \frac{1}{2} H_2 + Hg$ Overall : $NaCl + H_2O \rightarrow NaOH + \frac{1}{2} H_2 + \frac{1}{2} Cl_2$	4 4
3	**Attempt any four**	**16**
a)	**Phosphorous** Raw material:	1

	Phosphate rock, coke, sand Reaction: $2Ca_3(PO_4)_2 + 10C + 6SiO_2 = P_4$ (Yellow) + 6 $CaSiO_3$ + 10CO P_4 (Yellow) + heating = P_4 (Red) Phosphate rock is ground, mixed with portion of coke requirement, then sintered into nodules to obtain better electrical resistivity characteristics and to avoid entrainment of fines in the released phosphorous and carbon monoxide vapors. Screening is necessary to maintain size control with fines recycled to the sintering operation. Coke breeze and sand particles are mixed in controlled quantities based on phosphate rock analysis. The electrical 3 phase furnace is at 230-300V designed with power fed to 100-150cm diameter carbon electrode on each phase. The feed charge drops gradually into the fused section of the furnace at 1400^{o}C where the reduction to elemental phosphorous takes place. The furnace is kept under slight vacuum by fans in the downstream end of the plant, so the furnace gases moves to electrostatic precipitator to remove dust and then water cooled condenser. Liquid yellow phosphorous is collected under water. CO obtained is used as fuel. Molten slag obtained from furnace can be used as raw material for furnace.	3
b)	**Travelling pan filter** After reaction of phosphate rock and sulfuric acid slurry of gypsum + phosphoric acid is formed. It is separated in traveling pan filter. filter is suitable for continuous filtration of rapid settling, free filtering solids and is designed for ease of installation and simple reliable operation. Pan filters provide rapid de-watering and efficient cake washing at large capacities.	4
c)	**Phosphorus pentachloride** Phosphorus pentachloride is prepared in two stages. 1) Preparation of	2

	phosphorous trichloride 2) Chlorination of Phosphorus trichloride. Phosphorous trichloride is prepared by direct reunion of phosphorus and chlorine, the reaction being exothermic and spontaneous. $P_4 + 6Cl_2 \longrightarrow 4 PCl_3$  Liquid phosphorous and chlorine gas are fed in reactor. PCl_3 formed is partly refluxed in the reflux and a part is passed through a condenser and then to a still for distillation and finally for storage. It is analyzed for elemental phosphorus. Based on this analysis, additional chlorine is introduced to remove traces of unreacted phosphorus. Phosphorus pentachloride is conveniently prepared by passing excess of dry chlorine over liquid phosphorus trichloride in a tank cooled by a freezing mixture. PCl_3 is added drop by drop into it. The unused chlorine is removed by another tube and recycled again.	2

	$PCl_3 + Cl_2 \longrightarrow PCl_5$	
d)	**HCL by Salt and Sulphuric acid method:** $NaCl + H_2SO_4 \longrightarrow NaHSO_4 + HCl$ $NaHSO_4 + NaCl \longrightarrow Na_2SO_4 + HCl$ Both reactions involve the displacement of volatile acid from salt. The equilibrium can be displaced in desired direction by choice of condition i.e. promoting volatilization of HCl The high temperature process is superior to vacuum for this purpose. To promote reaction rate it is desirable to have temperature sufficiently high to keep at least one of the reacting component in liquid condition. There is no difficulty in first stage of decomposition but second stage required temperature of about 400 ˚C to liquefy $NaHSO_4$. The higher limit to temperature is the attack of corrosive relative mass on furnace. The product and unconverted H_2SO_4 is send to further processing in which there is recovery of H_2SO_4 by cooling and HCL is recovered as main product from absorber. 	1 2 1

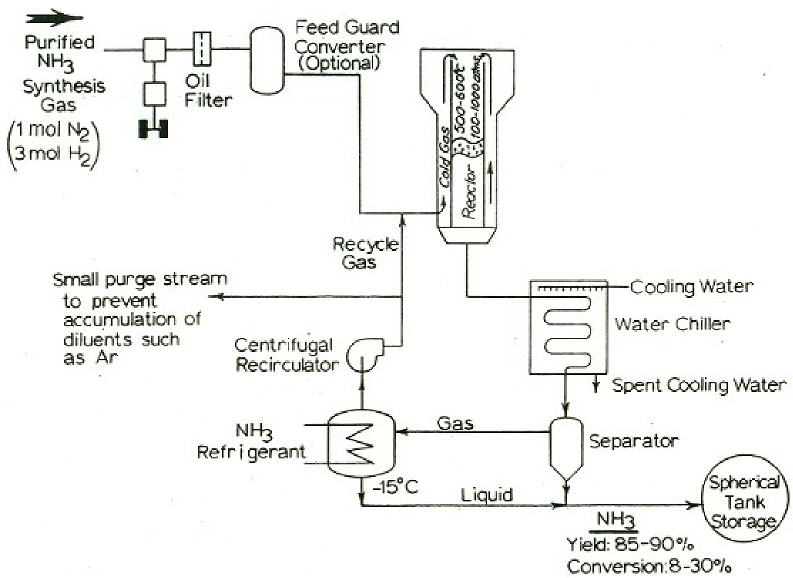
e)	**Use of soda ash(any 4)** • Glass manufacturing • Soap/detergents • Pulp and paper • Desulfurization • Textile processing	2
	Reactions in carbonating tower $CO_{2\,(g)} + OH^- \rightleftharpoons HCO_3^-$ $CO_{2\,(g)} + H_2O \rightleftharpoons HCO_3^- + H^+$ $Na^+ + Cl^- + NH_4^+ + HCO_3^- \longrightarrow NH_4^+Cl^-_{(aq)} + NaHCO_3\downarrow$	2
f)	**Ammonisation tower**: Ammonia is absorbed in ammoniation tower in purified brine. Some amount of CO_2 is also absorbed.	2
	Carbonating tower: In the second step, ammoniated brine is allowed to trickle down a carbonating tower known as solvay tower. This tower is also fitted with baffle plates. Here brine is mixed with carbon dioxide gas, produced by heating lime stone in a separate chamber called "kiln".The baffle plates ensure the flow of solution and breaks up carbon dioxide into small bubbles to produce good conditions for reaction.	2
4	**Attempt any four**	**16**
a)	**Soda ash**	4

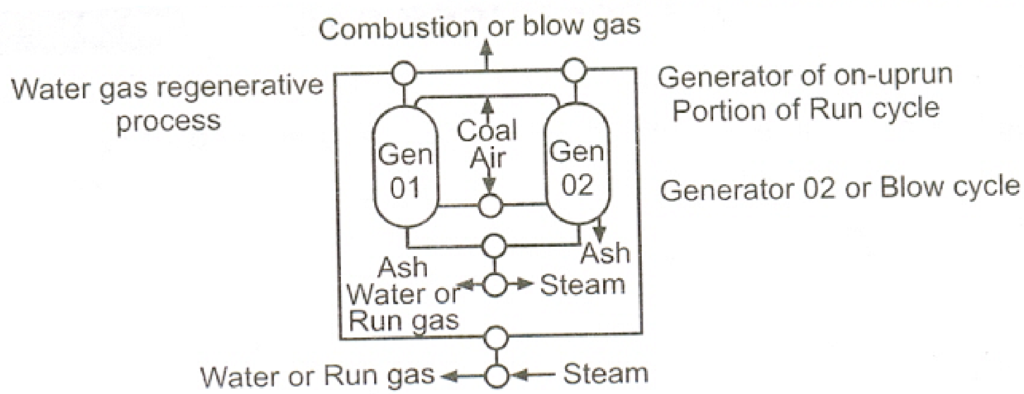


b)	**Pollution control in superphosphate process** When phosphate rock reacts with acid the SiF_4 and HF fumes are formed. These are scrubbed in water and silica is removed by NaCl. Chemical reaction involved in pollution control for single super phosphate i)$4HF+SiO_2 \rightarrow SiF_4+2H_2O$ ii)$3SiF_4+2H_2O \rightarrow 2H_2SiF_6+SiO_2$ iii) $H_2SiF_6+2NaCl \rightarrow Na_2Sif_6+2HCl$	4
c)	**Plaster of Paris,** quick-setting gypsum plaster consisting of a fine white powder (calcium sulfate hemihydrate), which hardens when moistened and allowed to dry. Known since ancient times, plaster of paris is so called because of its preparation from the abundant gypsum found near Paris. **Uses(any 2)** passive fire protection, as fireproofing products Insulation	2 2

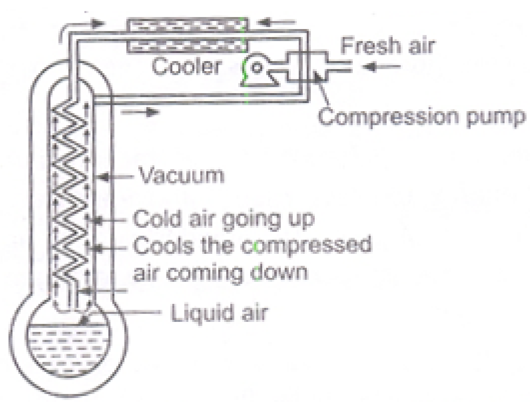
	Filler in fertilizer Decorative purpose	
d)	**Difference between yellow and red phosphorous** <table><tr><th>Yellow phosphorus</th><th>Red phosphorus</th></tr><tr><td>Melting point = 44.1 ^oC</td><td>Melting point = 593 ^oC</td></tr><tr><td>Ignite spontaneously in air</td><td>Higher resistance to oxidation</td></tr><tr><td>Highly toxic</td><td>Comparatively Less toxic</td></tr><tr><td>Lesser denser</td><td>Higher Denser</td></tr><tr><td>Used for the production of P_2O_5 and phosphoric acid</td><td>Used in safety matches, tracer bullets, incendiary devices, pesticides, pyrotechnic devices</td></tr></table>	One mark each for any four
e)	**CLAUDES PRINCIPLE** When a cooled compressed gas is allowed to some external work e.g. pushing the piston of gas engine, it falls in temperature. **LINDES PRINCIPLE** The principle underlying is joule – Thomson effect which states that when a gas under pressure is allowed to expand suddenly through a small orifice into a region of low pressure it falls in temperature.	2 2
f)	**Properties of hydrogen(any 4)** Hydrogen has a melting point of -259.14 °C and a boiling point of -252.87 °C. MW (H2) = 2 Hydrogen gas is highly flammable and will burn in air at a very wide range of concentrations between 4 percent and 75 percent by volume.	2

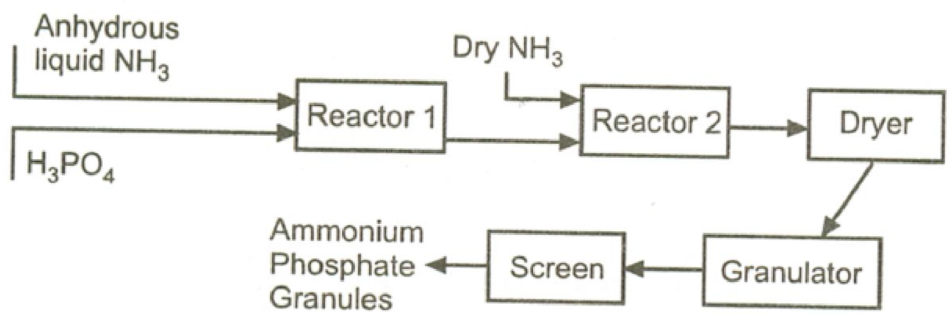
	Uses of hydrogen (any four) • For the production of ammonia • For the production of inorganic acids • As a fuel in rocket • As a coolant in generator • For the hydrogenation of vegetable oil • For enhancement of plasma welding • It is used as automobile fuels	2
5	**Attempt any two**	**16**
a)	**Ammonia** Raw Material: Synthesis gas, Air Reaction : $N_2+3H_2 =2NH_3$ Process Ammonia synthesis gas is compressed to the operating pressure. It is send through a filter to remove compression oil and additionally through a high temperature guard converter to convert carbon monoxide, carbon dioxide to methane and remove traces of water vap, hydrogen sulfide. This is done by catalyst and suitable getter material. The relatively cool gas is added along the outside of converter tube walls to provide cooling so that carbon steel can be used for the thick wall pressure vessel and internal tubes. The preheated gas flows next through the inside of the tubes which contain promoted porous iron catalyst at 550^{o}C. The ammonia product with an 8-30% conversion depending on process condition is removed by condensation, first with water cooling and then ammonia refrigeration. The	1 4

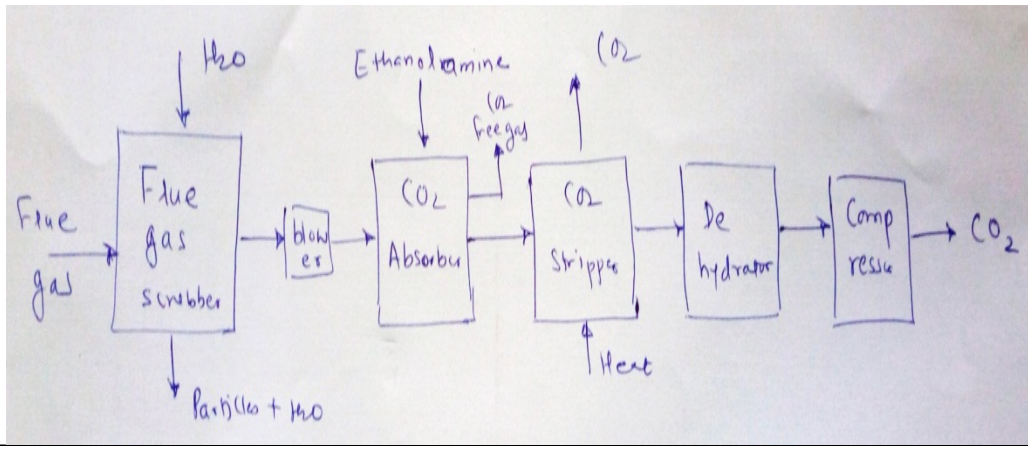
	unconverted N_2-H_2 mixture is re circulated to allow 85-90% yield.  	3
b) i)	**Composition** Producer gas composition CO = 21.7%, CO_2 = 12.5%, H_2 = 21.1%, CH_4 = 3.3%, N_2 = 41.4% (Vol%) Water gas composition CO = 40%, CO_2 = 63%, H_2 = 45%, N_2 = 4% (Vol%)	1+1
ii)	**Water gas**	4

		
iii)	**Use of producer gas** • As a fuel in steel industry • As fuel in engines • Producer gas can fuel hot-air generators of the kind used to produce hot air in industries such as those involved with making fertilizer and cement. • It can also be used for heating water in a number of applications for industry. • Another use is its suitability for use for melting glass in the production of artifacts.	2
c) i)	**Urea by Montecatini Process:** Chemical reaction: i) CO_2(carbon dioxide) + $2NH_3$ (ammonia) → $NH_4.COO.NH_2$ (ammonium carbamate) ii) $NH_4.COO.NH_2$ (ammonium carbamate) → $NH_2.CO.NH_2$ (urea) + H_2O iii) Undesirable side reaction : $NH_2.CO.NH_2$ (urea) → $NH_2.CO.NH.CO.NH_2$ (biuret) + NH_3	2

	Process description : Ammonia and carbon dioxide are compressed separately and added to the high pressure autoclave which must be water cooled due to highly exothermic reaction. The average residence time in the autoclave, which is operated on a continuous basis, is 1.5 to 2 hrs. a mixture of urea, ammonium cabamate, water and unreacted NH_3 and CO_2 results. This liquid effluent is let down to 27 atms and feed to a special flash evaporator containing gas liquid separator and condenser. unreacted NH_3, CO_2 and water as a solution are removed and recycled. An aqueous solution of carbamate urea is passed to the atmospheric flash drum where further decomposition of carbamate takes place. The off gases from this step can either be recycled or sent to ammonia process for making chemical fertilizers. The 80% aqueous urea solution can be used as it is or sent to a vacuum evaporator to obtained molten urea containing less than 1% water. The molten mass is them sprayed into prilling or granular solidification tower. To avoid formation of biuret in percentage > 1% , the temperature must be kept just above the melting point for processing time of 1-2 seconds in this phase of the operation.	2
ii)	**Resin from urea** : Urea-formaldehyde It is used in adhesives, finishes, particle board, MDF, and molded objects.	2+2
6	**Attempt any four**	**16**
a)	**LINDES PROCESS:** Principle: the principle underlying is joule – Thomson effect which states that when a gas under pressure is allowed to expand suddenly through a small orifice into a region of low pressure it falls in temperature.	1

	During expansion work is not done against external pressure but against internal attraction force between the molecules. Flow diagram:  Process description: Air free from CO_2 is compressed to about 200 atm pressure, and cooled by passing through a pipe surrounded by cold water. this cooled and compressed air passes through a spiral and escape through a small orifice or nozzle, when it is cooled by the above effect. This cooled air passes upwards surrounding the spiral pipe and cools the down coming air there in. The cooled air is further cooled by expansion and cooling is thus continued till it begins to condense. The up going air is compressed once again and is recirculated. Oxygen and nitrogen are separated from liquid air according to their boiling point.	2 1
b)	**Comparison between dry &wet process** Dry process- 1) Cheaper 2) Accurate control of raw materials is not possible. 3) Raw materials are mixed in dry condition 4) the dry process is used for the mfg. of cement when the raw material is either cement rock or blast furnace slag. Wet process- 1) Costlier 2) Accurate control of raw materials possible.	1 mark for each point

	3)Raw materials are mixed with water. 4) This process is used for any raw materials.	
c)	**Ammonium Phosphate** Anhydrous and dry ammonia and phosphoric acid are charged into the first reactor. About 80% neutralization is done in the first reactor. Further ammonia is added to second reactor. So conversion to the di-ammonium salt is obtained. The reaction is exothermic and hence due to heat of reaction the excess ammonia vapors are given out this are collected at the top of the tank and recharged. This cuts ammonia losses. The slurry obtained in second reactor is allowed to pass to a rotary adiabatic dryer in which moisture is reduced to less than 1%. The bed of dry particles is recycled by moving them through rotating drum granulator. The particles are screamed and dried further white crystalline solid material is obtained.  	2 2
d) i)	**Dry ice:** is the solid form of carbon dioxide. It is used primarily as a cooling agent. **Flue gases:** are the gases exiting to the atmosphere via a flue, which is a pipe or channel for conveying exhaust gases from a fireplace, oven, furnace, boiler or steam generator.	1 1
ii)	**Block diagram of CO_2 production (from flue gas)**	Marks



can be given for any method

e) **Single and triple super phospahte**

Parameter	**Single Superphospahte**	**Triple Superphosphate**
Raw material	Phosphate rock, sulfuric acid	Phosphate rock, phosphoric acid
Uses	Fertiliser	Fertiliser
Reaction	$[Ca_3(PO_4)_2]_3CaF_2 + 7H_2SO_4 = 3CaH_4(PO_4)_2 7CaSO_4 + 2HF$	$CaF_2.3Ca_3(PO_4)_2 + 14H_3PO_4 = 10Ca(H_2PO_4)_2 + 2HF$
Process	It requires 24 hours storgae	It can directly granulated after reaction.

One mark for each

f) **Mixed fertiliser** typically refers to a fertiliser containing two or more of the elements of nitrogen, phosphorus and potassium (NPK) which are essential for promoting plant growth and high crop yields. They are obtained by thoroughly mixing the ingredients either manually or mechanically.NPK mixture fertilisers are formulated and recommended by agricultural scientists to enhance the output of crops by giving it specific and exclusive blend of plant nutrients. They are slow releasing by nature and remain in the field for a long time. They are tailor made as per the soil and are crop specific.

2

	Mixed fertilisersare important because: • Use of mixed fertilisers results in reduction of labour costs as applying a mixture consumes lesser time as compared to applying the components separately. • Micro nutrients which help in increasing soil organic matter content are applied in small amounts to the soil. They can be incorporated in fertiliser mixtures. This facilitates uniform soil application of plant nutrients. • If a proper mixture suits a particular soil type and crop, the use of a fertiliser mixture leads to balanced manuring. It results in higher crop yield. • Being in granulated form, mixtures have a better physical condition and hence their application is easier. • Residual acidity of offertilisers can be controlled by using neutralisers in the mixture.	2