WINTER–19 EXAMINATION

Model Answer

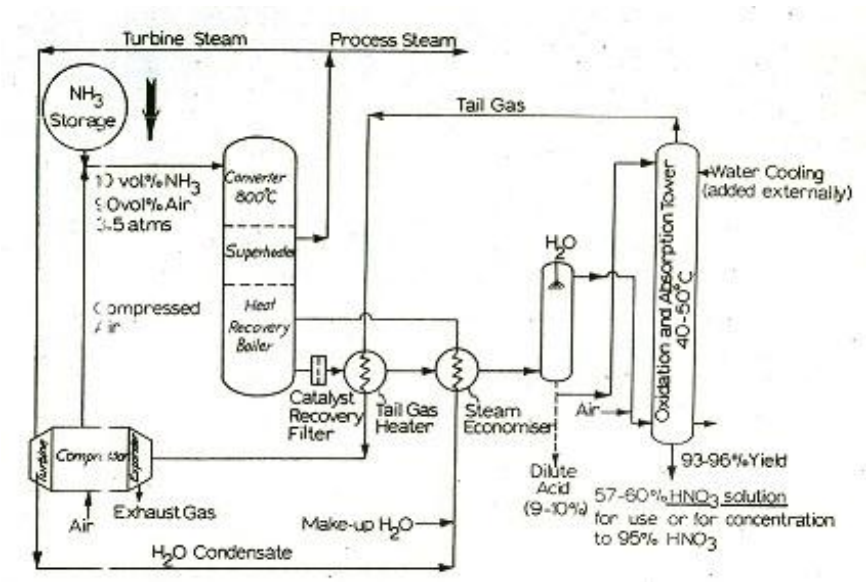
Subject Name: Technology of Inorganic Chemicals **Subject Code**: 22314

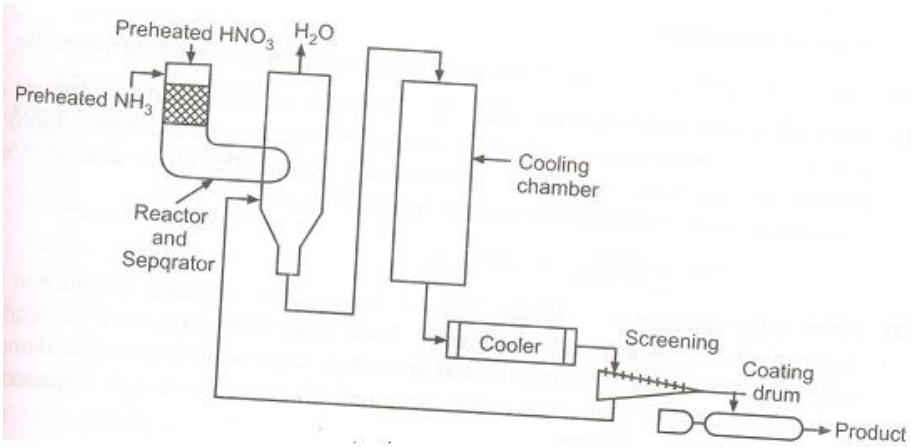
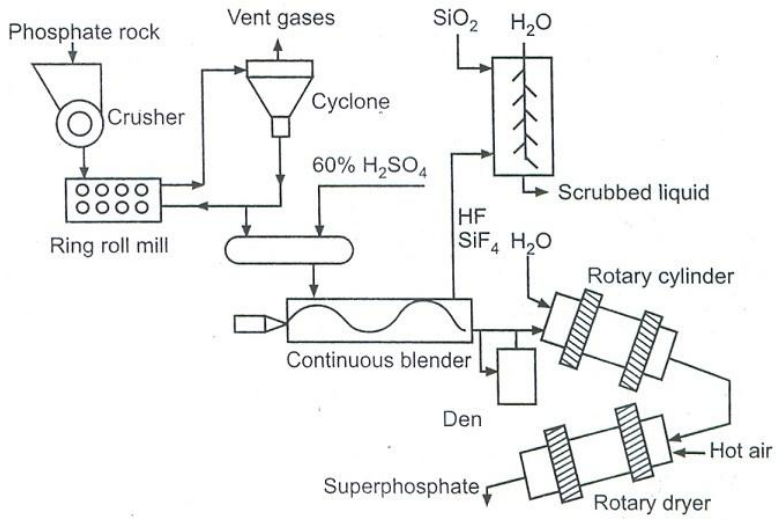
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. 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 constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

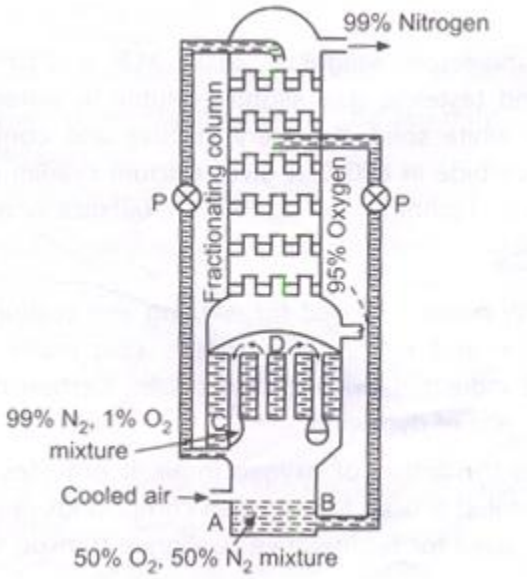
Q. No.	Sub Q. N.	Answer	Marking Scheme
1		**Attempt any five of the Following**	**10**
	a)	Industrial Fuel Gases • Producer gas • Water gas • Hydrogen • Propylene • Acetylene • Natural gas • LPG	½ mark each for any 4
	b)	**Cement** It is a powdery substance made by calcining lime and clay, mixed with water to form mortar or mixed with sand, gravel, and water to make concrete.	2
	c)	**Cell notation for diaphragm cell**	2

		Anode: $\uparrow Cl_2$, C | NaCl (aq) Cathode: NaOH (aq) | Fe, $H_2 \uparrow$ Cell reaction : Anode : $Cl^- - e^- \rightarrow \frac{1}{2} Cl_2$ Cathode : $Na^+ + H_2O + e \rightarrow Na^+ + OH^- + \frac{1}{2} H_2$ Overall : $NaCl + H_2O \rightarrow NaOH + \frac{1}{2} H_2 + \frac{1}{2} Cl_2$	
	d)	**Uses of Phosphorous : (any 2)** It is used to prepare • phosphoric acid • phosphate builders for detergents • phosphorous trichloride • phosphorus pentachloride • gasoline lube oil additives • fireworks • flame retardants • matches	1 mark each
	e)	**Industrial applications of ammonia** 1. For production of urea 2. For production of nitric acid 3. For production of ammonium nitrate 4. For production of ammonium phosphate 5. As refrigerant 6. In food industry	1 mark each for any 2
	f)	**Catalyst used for manufacturing of sulfuric acid** • Platinum • Vanadium Pent oxide	1 mark each

	g)	**Raw material for manufacturing Urea** • Carbon dioxide • Ammonia	1 mark each
2		**Attempt any three of the following**	**12**
	a)	**PFD for manufacturing of Nitric Acid**  	4
	b)	**Ammonium Nitrate** **Process description** – In the Stengel process, vapours of ammonia & nitric acid are mixed in a stainless steel reactor. The reaction is exothermic & hence heat is given out. The mixture of steam & molten ammonium nitrate is fed to cyclone type separator. The molten mass is solidified on the water cooled stainless steel belts .Then material is passed to a grinder where is the material is crushed dried and ground to flake size then, ammonium nitrate flakes are coated with clay. **Reaction** $HNO_3 + NH_3 \rightarrow NH_4NO_3$	2

			2
	c)	**PFD of super phosphate** 	4
	d)	**Ammonia Recovery in Solvey's process** CaO is formed as a by-product of the thermal decomposition of limestone in the lime kiln. This CaO enters a lime slaker to react with water to form calcium hydroxide: $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)}$ The calcium hydroxide produced here is reacted with the ammonium chloride separated	4

		out of the carbonating tower by filtration in combined ammonia still. Free ammonia is recovered by heating ammonium chloride before reacting with calcium hydroxide. $Ca(OH)_{2(aq)} + 2NH_4Cl_{(aq)} \rightarrow CaCl_{2(aq)} + 2H_2O_{(l)} + 2NH_{3(g)}$ The ammonia is recycled back into the process to form ammoniated brine.	
3		**Attempt any three of the following**	**12**
	a)	**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. **Setting of cement** The term **Setting** is used to describe the stiffening of the cement paste. Setting of cement refers to changes of cement paste from a fluid to rigid state. The setting characteristics of Portland cement paste are defined by initial set and final set. Initial set indicates the approximate time at which the paste begins to stiffen considerably. Final set roughly indicates the time at which the cement paste has hardened and can support some load. Initial setting time indicates the beginning of the setting process when the cement paste starts losing its plasticity. Final setting time is the time elapsed between the moment water is added to the cement and the time when the cement completely lost its plasticity and can resist certain definite pressure.	2 2
	b)	**CLAUDES PROCESS:** **Principle:** when a cooled compressed gas is allowed to some external work e.g. pushing the piston of gas engine, it falls in temperature. **Flow diagram:**	2



Process description:

Air freed from CO_2 is dried, compressed and passes through a pipe surrounded by cold oxygen and nitrogen, where it is cooled. Cooled and compressed air is allowed to do work in an expansion engine where it is further cooled.

This cooled air enters the plant and rises through iron tubes surrounded by liquid oxygen. a part of the air gets liquefied and collects. the condensation is 50% N2,50%O2 .the gas which escape condensation passes downwards through side tubes surrounded by liquid oxygen and condenses. The condensation being 99% N_2 and 1% O_2

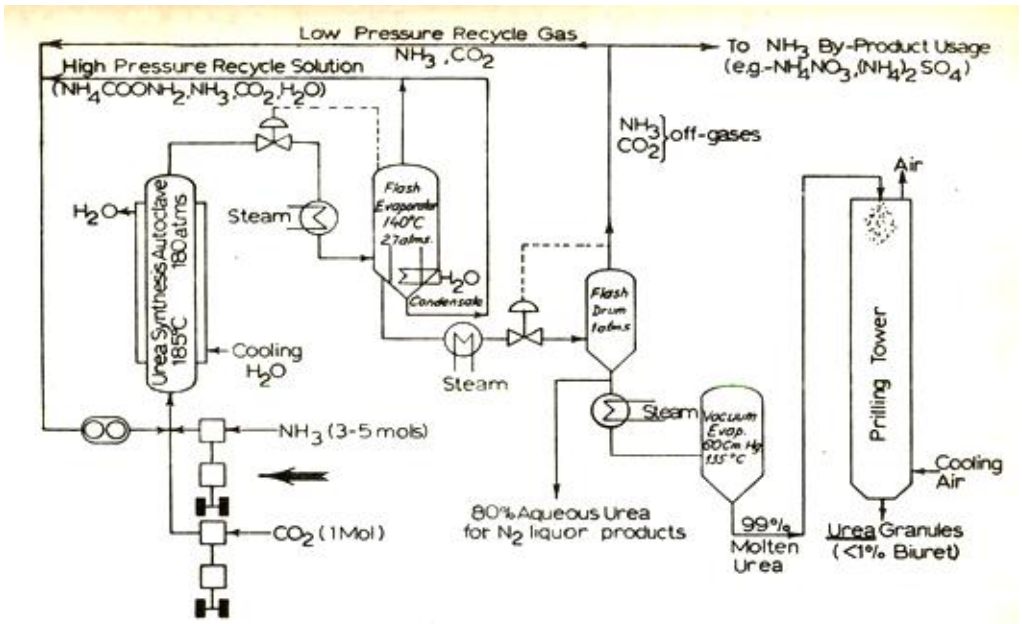
The condensed liquid is pumped to the top of fractionating column, while the bottom liq. Is pumped to a level slightly above the fractionating column, where it meets an upward current of gases. the liq is wormed up a little as it comes down and loses a volatile constituents more and more. i.e. N_2 bye evaporation and gets gradually richer in O_2 . similarly up going gases loses more and more O_2 by condensation due to cooling and gets richer in N_2.by the time gases rich the top, it is 99% pure N_2 which escape to the exit provided. Liq O_2 evaporate as it cools the air and escape to the exit indicated

2

c) **Properties of sulfuric acid**

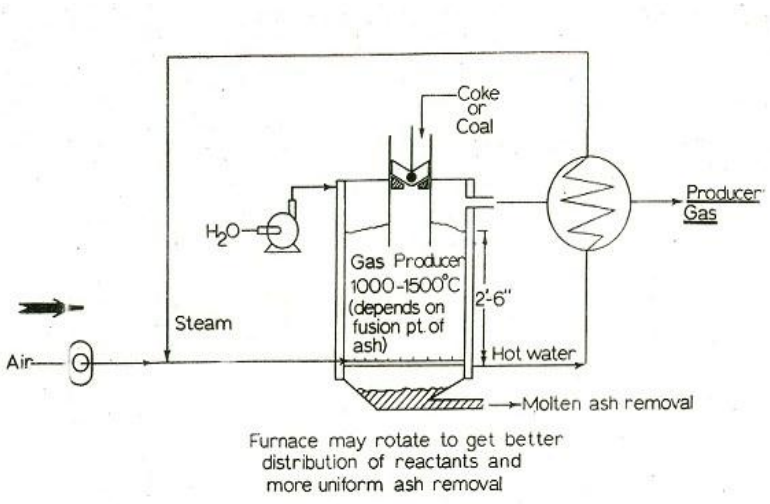
- Molecular weight: 98
- Melting point 10.5 ^oC

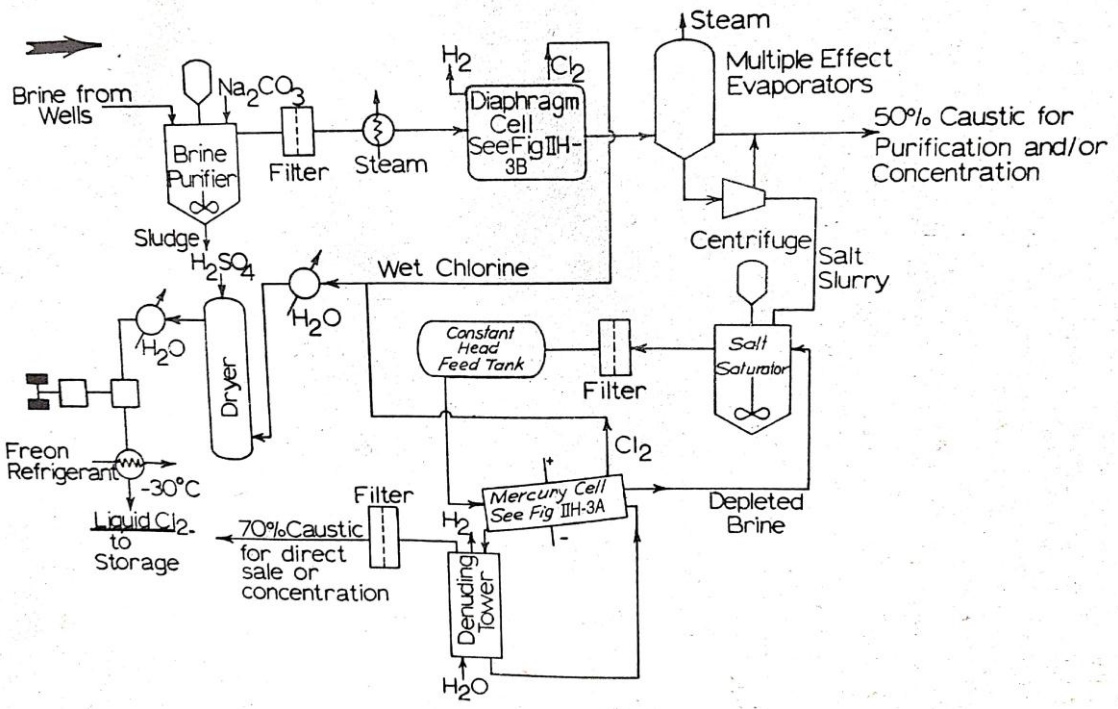
1 mark each for any 2

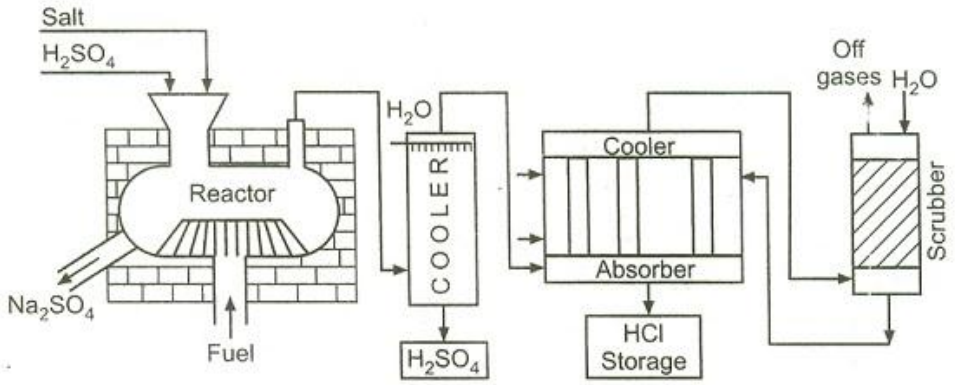
		• Boiling point 340°C with decomposition • Completely miscible with water with large heat of solution • Formation of oleum with SO_3 **Uses of sulfuric acid (any two)** **Used in or as** • For manufacturing of Fertilizers • Oil refining • Metal processing • Manufacturing of Rayon • In Lead acid batteries • Detergent manufacturing	properties 1 mark each for any 2 uses
	d)	**PFD for manufacturing of Urea**  	4
4		**Attempt any three of the following**	**12**
	a)	**Single and triple super phospahte w.r.t. raw material, uses and chemical formula**	4

Parameter	Single Superphospahte	Triple Superphosphate
Raw material	Phosphate rock, sulfuric acid	Phosphate rock, phosphoric acid

			Uses	Fertiliser	Fertiliser
			Chemical Formula	$3CaH_4(PO_4)_27CaSO_4$	$10Ca(H_2PO_4)_2$
	b)	**Mixed fertilizers are important because:** • Use of mixed fertilizers 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 fertilizer mixtures. This facilitates uniform soil application of plant nutrients. • If a proper mixture suits a particular soil type and crop, the use of a fertilizer 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 fertilizers can be controlled by using neutralizers in the mixture.		4
	c)	**Classification of Refractory** 1) Acid refractories 2) Basic Refractories 3) Neutral Refractories **Acid refractories** The raw material used for silica bricks is ganister, a fine grained quartzite rock containing 97 to 98 %. The rock is crushed ground with water and mixed with 2 % lime. The mixture is moulded into bricks in a power press allowed to dry and then ultimately bagged in high temperature kiln at 1500 ^oC -1600 ^{o} C. The lime being basic reacts chemically with acidic $SiO_2$and fuses at number of places .in a brick and gives it strength. The bricks expand by about 3.5%after high temperature backing is finished. Silica bricks are extremely hard, refractory and able to withstand a load of 3.5 Kg per sq. cm. at 1600^o C .Their ability to withstand fluctuation in temperature is very poor.		2 2

		Silica bricks are suitable for furnaces which are most of the time exposed to uniformly high temperature. ***Note: Description of Basic and Neutral refractories can also be given marks.***	
	d)	**Producer gas**, It is a mixture of flammable gases (principally carbon monoxide and hydrogen) and nonflammable gases (mainly nitrogen and carbon dioxide) made by the partial combustion of carbonaceous substances, usually coal, in an atmosphere of air and steam. Steam and air mixture injected in the bottom of water cooled jacket steel furnace equipped with rotating grate to remove fusible ash as shown in figure. Solid fuel is added from hopper valve on the top. Producer gas is cooled by passing through waste heat boiler.  	2 2
	e)	**PFD of manufacturing process of Caustic Soda and Chlorine**	4

			
5		**Attempt any two of the following**	**12**
	a)	**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.	Reaction 1 mark + Process 2 marks + PFD 3 marks

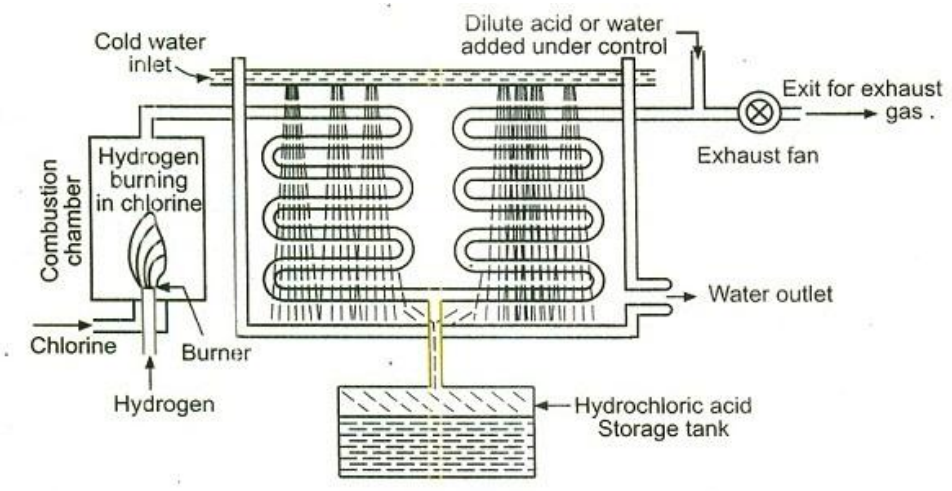


Or

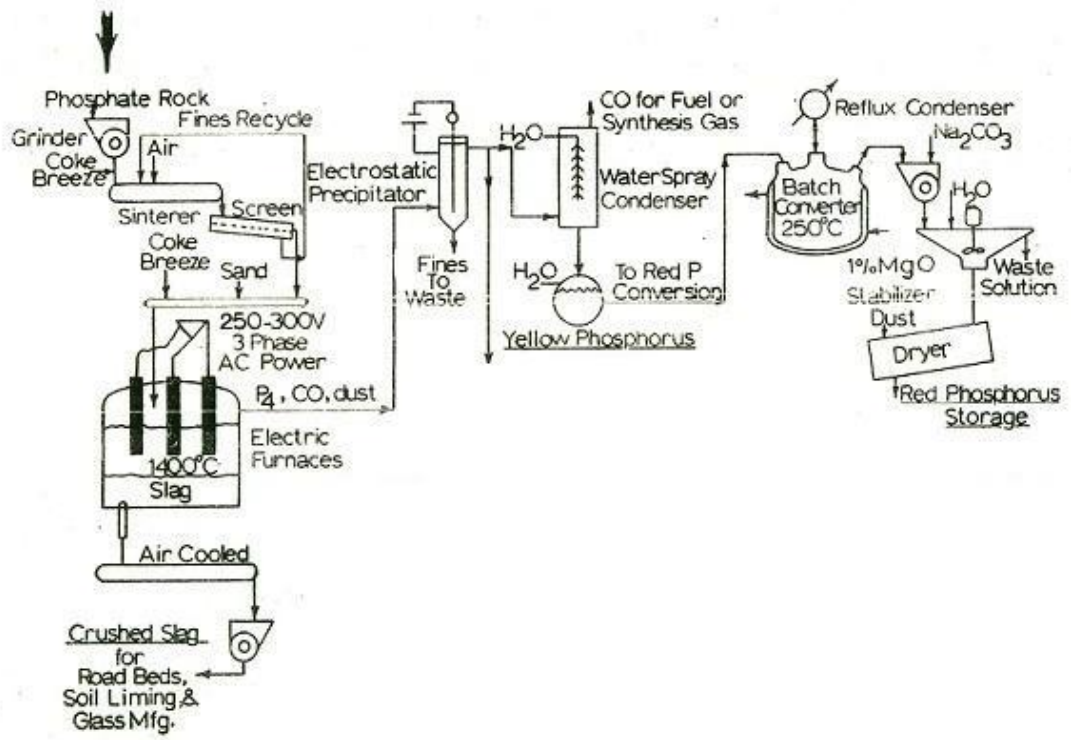
Synthesis process for HCl

The process generates hydrogen chloride by burning chlorine in a few percent excess of hydrogen; chlorine and hydrogen are obtained as by products during manufacture of caustic soda.

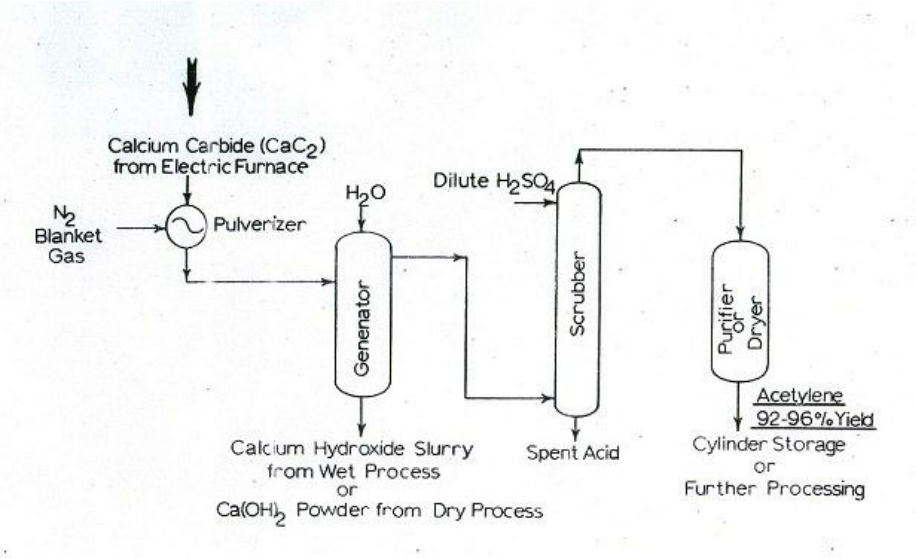
$H_2 + Cl_2 \longrightarrow 2\ HCl$



Dry hydrogen is made to burn in acid resisting burner fitted in a combustion chamber lined with silica bricks. Dry chlorine is passed into the combustion chamber when hydrogen burns in an atmosphere of chlorine to give HCl. The gas is passed through a cooler cooled by water spray and then through absorber through which water flows down in controlled quantities. The absorber is also cooled by a spray of cold water to remove the heat of absorption of HCl in water. The solution of HCl flows into storage tank

		below. An exhaust fan on the extreme right pumps out the waste gases which escape in the atmosphere.	
	b)	**Manufacturing of Urea w.r.t following points** 1. **Temperature:** Urea production rate increases as temperature increases up to 180°C and then fall sharply. 2. **Pressure:** Urea production rate increases as pressure increases. Pressure maintained is 180 atm. 3. **Formation of biuret:** Formation of biuret is not desirable in urea. It forms when two urea molecules combine with each other. It can be avoided by keeping urea solution temperature just above melting point before sending to prilling tower. $2NH_2.CO.NH_2 = NH_2.CO.NH.CO.NH_2 + NH$	2 2 2
	c)	**PFD for phosphorus manufacturing**  	6
6		**Attempt any two of the following**	**12**

	a)	**Mixed fertilizer** typically refers to a fertilizer 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. **Mixed fertilizer reactions** $NH_3 + H_3PO_4 = NH_4H_2PO_4$ $NH_4H_2PO_4 + NH_3 = (NH_4)_2HPO_4$ DAP+UREA+POTASH+FILLER = MIXED FERTILISER **30-30-40** means 30% N2, 30% P and 40% K	2 1 mark each for any 2 reactions 2
	b)	**Acetylene from CaC_2** **Raw materials:** lime stone, coke, water **Chemical reactions:** $CaO + 3C \rightarrow CaC_2 + CO$ $CaC_2 + H_2O \longrightarrow Ca(OH)_2 + CH{\equiv}CH$ **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 C_2H_2 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. 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	Reaction 1 mark + Process 2 marks + PFD 3 marks

		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.  	
	c)	**Physico-Chemical principles in sulfuric acid production** **Temperature** Sulfur dioxide and oxygen then react as follows: $2\ SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)} : \Delta H = -197\ kJ \cdot mol^{-1}$ According to the Le Chatelier's principle, a lower temperature should be used to shift the chemical equilibrium towards the right, hence increasing the percentage yield. In order to get as much sulphur trioxide as possible in the equilibrium mixture, you need as low a temperature as possible. **Pressure** $2\ SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)} : \Delta H = -197\ kJ \cdot mol^{-1}$ 2 mol + 1 mol = 2 mol	2 2

		Notice that there are 3 molecules on the left-hand side of the equation, but only 2 on the right. According to Le Chatelier's Principle, if you increase the pressure the system will respond by favouring the reaction which produces fewer molecules. That will cause the pressure to fall again. In order to get as much sulphur trioxide as possible in the equilibrium mixture, you need as high a pressure as possible. High pressures also increase the rate of the reaction. **Concentration** An excess of oxygen relative to the proportions demanded by the equation. $2\ SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)} : \Delta H = -197\ kJ \cdot mol^{-1}$ According to Le Chatelier's Principle, Increasing the concentration of oxygen in the mixture causes the position of equilibrium to shift towards the right. Since the oxygen comes from the air, this is a very cheap way of increasing the conversion of sulphur dioxide into sulphur trioxide.By increasing the proportion of oxygen you can increase the percentage of the sulphur dioxide converted, but at the same time decrease the total amount of sulphur trioxide made each day. The 1 : 1 mixture turns out to give you the best possible overall yield of sulphur trioxide.	2