



MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

Winter-17 EXAMINATION
Model Answer

Subject Name: Chemical Process Technology

Subject code : 17314

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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 one equivalent concept.



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Q No.	Answer	Marks
1A	Attempt any six	12
a)	Reactions in sulfuric acid manufacturing $S + O_2 = SO_2$ $SO_2 + \frac{1}{2} O_2 = SO_3$ $SO_3 + H_2O = H_2SO_4$	2
b)	Le Chatelier's Principle states: when a change is introduced to a system in equilibrium, the equilibrium shifts in the direction that relieves the change.	2
c)	Biuret It is the result of condensation of two molecules of urea and is a problematic impurity in urea-based fertilizers. $2 CO(NH_2)_2 \rightarrow H_2N-CO-NH-CO-NH_2 + NH_3$ biuret	1 1
d)	Types of cement(any 4) 1) Portland cement 2) Pozzolanic cement 3) Natural cement 4) High alumina cement 5) Super sulphate cement 6) Quick setting cement	½ mark each
e)	Gypsum $CaSO_4 \cdot 2H_2O$	2
f)	Single super phosphate $CaH_4(PO_4)_2 7CaSO_4$ Triple super phosphate $Ca(H_2PO_4)_2 \cdot H_2O$	1 1

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g)	Methods for manufacturing of HCL: <ol style="list-style-type: none"> 1. Salt and sulfuric acid 2. Synthesis process 3. Chlorination reactions 	1 mark each for any 2
h)	<p>Dry ice: is the solid form of carbon dioxide. It is used primarily as a cooling agent.</p> <p>Use :(any 2)</p> <p>Transportation freezing, blast cleaning, inert atmosphere in reveting, safe blasting of coal</p>	1 1
1B	Attempt any two	8
a)	<p>Cell notation for diaphragm cell</p> <div style="text-align: center; margin-bottom: 10px;"> Anode Cathode </div> <div style="margin-left: 10%; font-family: monospace;"> ↑ Cl₂, C NaCl (aq) NaOH (aq) Fe, H₂ ↑ </div> <p>Cell reaction :</p> <p>Anode : $\text{Cl}^- - \text{e}^- \rightarrow \frac{1}{2} \text{Cl}_2$</p> <p>Cathode : $\text{Na}^+ + \text{H}_2\text{O} + \text{e}^- \rightarrow \text{Na}^+ + \text{OH}^- + \frac{1}{2} \text{H}_2$</p> <p>Overall : $\text{NaCl} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \frac{1}{2} \text{H}_2 + \frac{1}{2} \text{Cl}_2$</p> <p>Cell notation for mercury cell</p>	2
		2



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	<div>Anode $\uparrow \text{Cl}_2 \mid \text{C, NaCl (aq)}$</div> <div>Cathode $\text{Na}^\circ \mid \text{NaHg}$</div> <div>Cell reaction :</div> <div>Anode : $\text{Cl}^- - \text{e}^- \rightarrow \frac{1}{2} \text{Cl}_2$</div> <div>Cathode : $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}^\circ$</div> <div>Denuding : $\text{NaHg} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \frac{1}{2} \text{H}_2 + \text{Hg}$</div> <div>Overall : $\text{NaCl} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \frac{1}{2} \text{H}_2 + \frac{1}{2} \text{Cl}_2$</div>											
b)	<div>PFD-Manufacturing of CO₂ by flue gas</div> <div><p>The diagram illustrates the manufacturing of CO₂ from flue gas. Key components include: Water tube boiler, Gas Scrubbers, Absorber reactor, Reboiler, CO₂ cooler, CO₂ condenser, Liquid CO₂, Dry ice press, Multistage turbine driven compressor with intercoolers, Dehydration drums, Scrubber, and Girbotol recovery unit. The process involves the absorption of CO₂ from flue gas using an ethanolic amine solution, followed by separation and compression.</p></div>	4										
c)	<div>Difference between yellow and red phosphorous</div> <table><tr><th>Yellow phosphorus</th><th>Red phosphorus</th></tr><tr><td>Melting point = 44.1 °C</td><td>Melting point = 593 °C</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></table>	Yellow phosphorus	Red phosphorus	Melting point = 44.1 °C	Melting point = 593 °C	Ignite spontaneously in air	Higher resistance to oxidation	Highly toxic	Comparatively Less toxic	Lesser denser	Higher Denser	One mark each for any four
Yellow phosphorus	Red phosphorus											
Melting point = 44.1 °C	Melting point = 593 °C											
Ignite spontaneously in air	Higher resistance to oxidation											
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Lesser denser	Higher Denser											



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		Used for the production of P ₂ O ₅ and phosphoric acid	Used in safety matches, tracer bullets, incendiary devices, pesticides, pyrotechnic devices		
2	Attempt any two				16
a)	Sulfuric acid production S + O ₂ = SO ₂ SO ₂ + ½ O ₂ = SO ₃ SO ₃ + H ₂ O =H ₂ SO ₄ Description: Molten sulfur is oxidized with air in burner. Heat produced is recovered in waste heat boiler. Gas stream containing 7-10% SO ₂ and 11-14 % O ₂ preheated by convertor gas and send to first stage reactor . The reacted temp is 500-600° C contained 30% catalyst and convert about 80% of SO ₂ . The converter product exchange heat at 300°C and sent to second stage where yield is increased to 97% at 400-450°C .The product gases are cooled to 150°C by water and air heat exchanger and absorbed in oleum fed at rate to allowed not over 1% rise in acid strength. Final scrubbing is done with lower strength.				Rection -2 Diagra m-3 Process -3

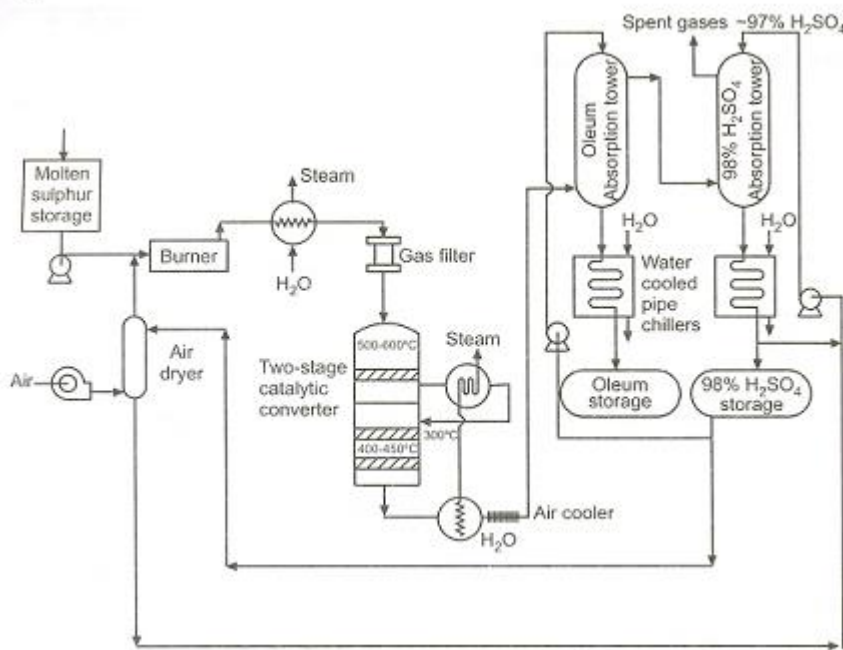
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b)

Urea by Montecatini Process:

Chemical reaction:

- i) $\text{CO}_2(\text{carbon dioxide}) + 2\text{NH}_3 (\text{ ammonia}) \rightarrow \text{NH}_4.\text{COO}.\text{NH}_2$
(ammonium carbamate)
- ii) $\text{NH}_4.\text{COO}.\text{NH}_2 (\text{ammonium carbamate}) \rightarrow \text{NH}_2.\text{CO}.\text{NH}_2 (\text{ urea}) + \text{H}_2\text{O}$
- iii) Undesirable side reaction :
 $\text{NH}_2.\text{CO}.\text{NH}_2 (\text{urea}) \rightarrow \text{NH}_2.\text{CO}.\text{NH}.\text{CO}.\text{NH}_2 (\text{biuret}) + \text{NH}_3$

Flow diagram :

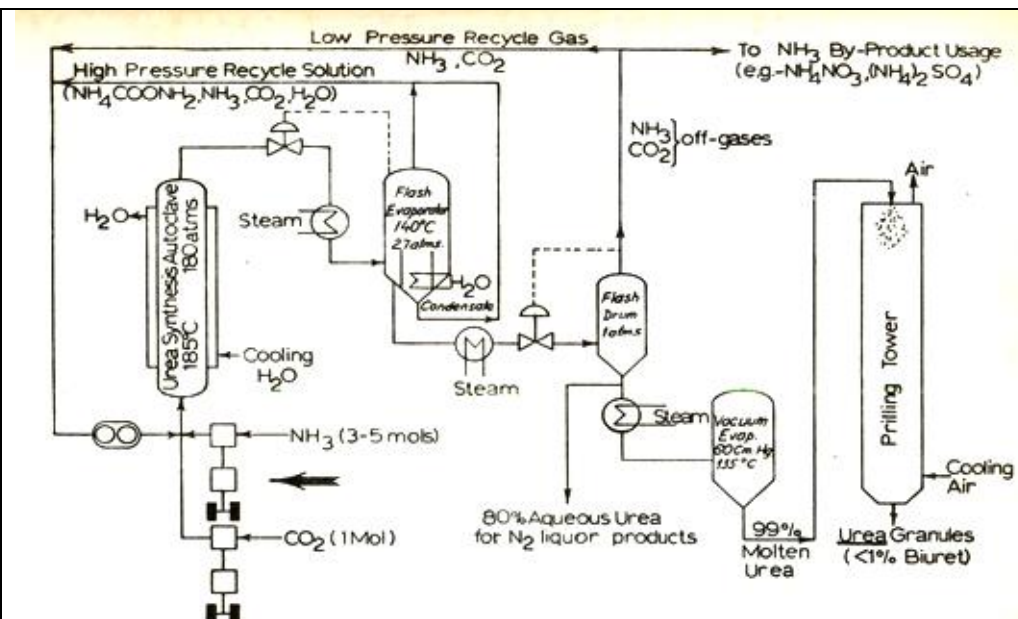
Rection

-1

Diagra
m-4

Process

-3



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 carbamate, 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 obtain molten urea containing less than 1% water. The molten

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mass is then 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.

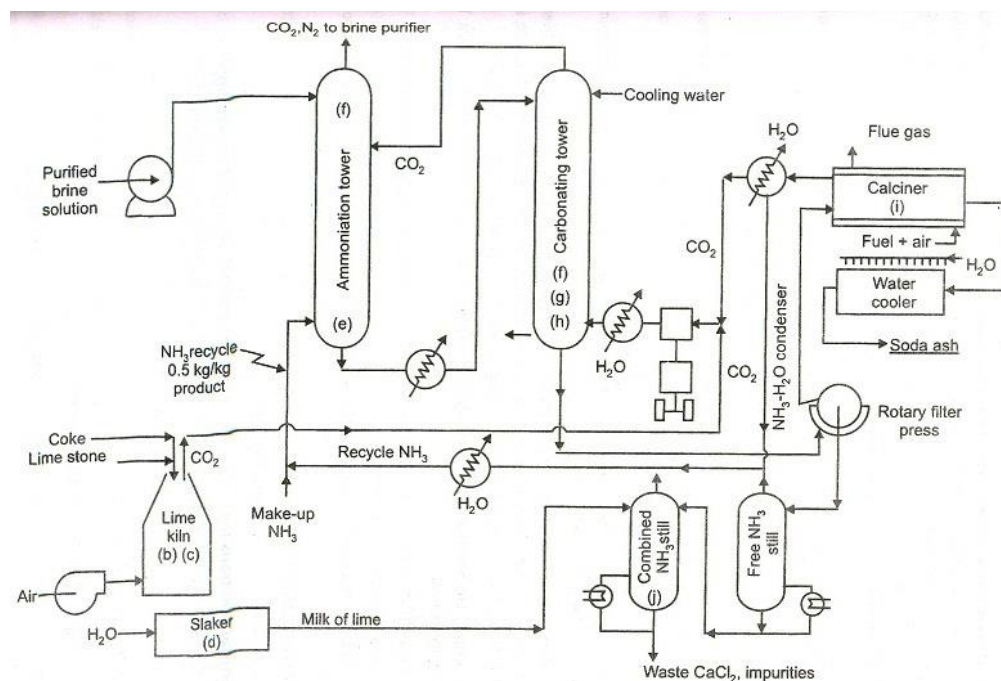
c)

Solvay process

The overall reaction can be regarded as between calcium carbonate and sodium chloride:



However, calcium carbonate is too insoluble to react with a solution of salt. Instead the product is obtained by a series of seven stages.



The process is known as the ammonia-soda process or the Solvay process, named after the Belgian industrial chemist who patented it in 1861. The various stages of the Solvay process are interlinked as can be seen from the

Reaction

-2

Diagra

m-3

Process

-3



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diagram and description below.

(1) Ammoniation of brine

Ammonia gas is absorbed in concentrated brine to give a solution containing both sodium chloride and ammonia. $\text{Na}^+(\text{aq})$, $\text{Cl}^-(\text{aq})$, $\text{NH}_4^+(\text{aq})$, $\text{OH}^-(\text{aq})$ ions and $\text{NH}_3(\text{aq})$ are present.

(2) Formation of calcium oxide and carbon dioxide

Kilns are fed with a limestone/coke mixture (13:1 by mass). The coke burns in a counter-current of pre-heated air:



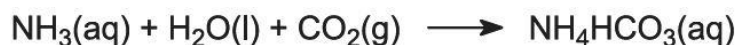
The heat of combustion raises the temperature of the kiln and the limestone decomposes:



The gas, containing approximately 40% carbon dioxide, is freed of lime dust and sent to the carbonating (Solvay) towers. The residue, calcium oxide, is used in ammonia recovery (see step 7 below).

(3) The Solvay Tower

This is the key stage in the process. The ammoniated brine from step (1) is passed down through the Solvay Tower while carbon dioxide from steps (2) and (5) is passed up it. The Solvay Tower is tall and contains a set of mushroom-shaped baffles to slow down and break up the liquid flow so that the carbon dioxide can be efficiently absorbed by the solution. Carbon dioxide, on dissolving, reacts with the dissolved ammonia to form ammonium hydrogencarbonate:





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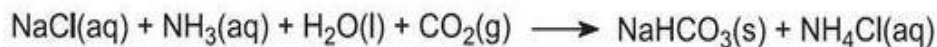
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The solution now contains ions $\text{Na}^+(\text{aq})$, $\text{Cl}^-(\text{aq})$, $\text{NH}_4^+(\text{aq})$ and $\text{HCO}_3^-(\text{aq})$. Of the four substances which could be formed by different combinations of these ions, sodium hydrogencarbonate (NaHCO_3) is the least soluble. It precipitates as a solid in the lower part of the tower, which is cooled. The net process is:



A suspension of solid sodium hydrogencarbonate in a solution of ammonium chloride is run out of the base of the tower.

(4) Separation of solid sodium hydrocarbonate

The suspension is filtered to separate the solid sodium hydrogencarbonate from the ammonium chloride solution, which is then used in stage (7).

(5) Formation of sodium carbonate

The sodium hydrogencarbonate is heated in rotating ovens at 450 K so that it decomposes to sodium carbonate, water and carbon dioxide:



The carbon dioxide is sent back to the Solvay Tower for use in step (3). The product of the process, anhydrous sodium carbonate, is obtained as a fine white powder known as light sodium carbonate.

(6) Formation of calcium hydroxide

The last two stages, (6) and (7), are concerned with the regeneration of ammonia from ammonium chloride (made in step 3). The quicklime from step (2) is slaked with excess water giving milk of lime:

**(7) Regeneration of ammonia**

This calcium hydroxide suspension is mixed with the ammonium chloride



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	<p>solution left from step (4) and heated:</p> $2\text{NH}_4\text{Cl}(\text{aq}) + \text{Ca}(\text{OH})_2(\text{aq/s}) \longrightarrow \text{CaCl}_2(\text{aq}) + 2\text{NH}_3(\text{g}) + 2\text{H}_2\text{O}(\text{l})$ <p>The ammonia is thus recovered, and sent back to step (1). Calcium chloride is the only by-product of the whole process.</p> <p>The overall process is an elegant one. In theory, the only raw materials are limestone and brine. Inevitably, there are losses of ammonia, and these are made up for by addition of extra supplies, as required in step (1)</p>	
3	Attempt any four	16
a)	<p>Triple superphosphate</p> <p>This material is much more concentrated fertilizer than ordinary superphosphate</p> <p>it contains from 45 to 46% of available P_2O_5 of nearly three times the amount in the regular superphosphate.</p> <p>Chemical reaction:</p> $\text{CaF}_2 \cdot 3\text{Ca}_3(\text{PO}_4)_2 + 14\text{H}_3\text{PO}_4 \longrightarrow 10\text{Ca}(\text{H}_2\text{PO}_4)_2 + 2\text{HF}$ <p>It is made by action of phosphoric acid on phosphate rock.</p> <p>The pulverized phosphate rock is mixed with phosphoric acid into a two stage reactor. The resultant slurry is sprayed into the granulator</p> <p>The product from the granulator is dried, screened, the oversize crushed and cooled again.</p> <p>Final product is conveyed to bulk storage where product is cured 4 to 6 weeks.</p> <p>During curing further reaction of acid and rock occurs which increases the availability of P_2O_5 for plants as food.</p> <p>Exhaust gases from granulator and cooler are scrubbed with water to remove</p>	<p>2</p> <p>2</p>



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	silicofluorides.	
b)	<p>Phosphorus pentachloride</p> <p>Phosphorus pentachloride is prepared in two stages. 1) Preparation of phosphorous trichloride 2) Chlorination of Phosphorus trichloride.</p> <p>Phosphorous trichloride is prepared by direct reunion of phosphorus and chlorine, the reaction being exothermic and spontaneous.</p> $P_4 + 6Cl_2 \longrightarrow 4 PCl_3$ <p>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.</p> <p>It is analyzed for elemental phosphorus. Based on this analysis, additional chlorine is introduced to remove traces of unreacted phosphorus.</p> <p>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.</p> $PCl_3 + Cl_2 \longrightarrow PCl_5$	<p>1</p> <p>1</p> <p>2</p>
c)	<p>Comparison between dry & wet process</p> <p>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.</p> <p>Wet process- 1) Costlier 2) Accurate control of raw materials possible. 3) Raw materials are mixed with water. 4) This process is used for any raw materials.</p>	1 mark each
d)	Water Gas (continuous process):	



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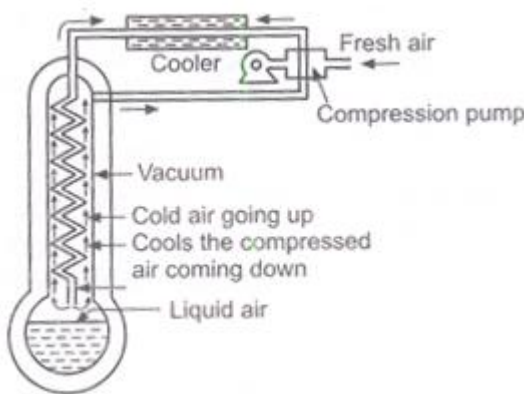
	$\text{C} + \text{O}_2 \longrightarrow \text{CO}_2$ $\text{C} + \text{H}_2\text{O} \longrightarrow \text{CO} + \text{H}_2$ <p style="text-align: center;">OR</p> <p>Water Gas (regenerative process):</p> <p>Blow period which heats carbon by reaction :</p> $\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$ <p>run period where endothermic reaction :</p> $\text{C(s)} + \text{H}_2\text{O(l)} \rightarrow \text{CO(g)} + \text{H}_2\text{(g)}$ <p>Producer gas</p> $\text{C} + \text{O}_2 \rightarrow \text{CO} + 97000\text{kcal}$ $\text{CO}_2 + \text{C} \rightarrow 2\text{CO} - 91000\text{cal}$ $\text{H}_2\text{O(Steam)} + \text{C} \rightarrow \text{H}_2\text{O} + \text{CO} - 30900\text{cal}$ $2\text{H}_2\text{O} + \text{C} \rightarrow 2\text{H}_2 + \text{CO}_2 - 20820\text{cal}$	2
e)	<p>LINDES PROCESS:</p> <p>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.</p> <p>During expansion work is not done against external pressure but against internal attraction force between the molecules.</p> <p>Process description:</p> <p>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.</p> <p>The cooled air is further cooled by expansion and cooling is thus continued till it begins to condense.</p>	2



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	<p>The up going air is compressed once again and is recirculated. Oxygen and nitrogen are separated from liquid air according to their boiling point.</p> <p>Flow diagram:</p> 	2
f)	<p>Properties of chlorine (any 2)</p> <p>MW : 35, MP: -101.5°C, BP : -34.4°C</p> <p>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.</p> <p>Uses of Chlorine(any 2)</p> <ol style="list-style-type: none"> 1. Pulp and Paper 2. PVC 3. Chlorinated paraffin wax 4. Pesticides and insecticides 5. Water treatment 6. Rayon grade wood pulp <p>Properties of caustic soda (any 2)</p> <p>MW : 40, BP : 1390°C, MP : 318°C , Very soluble in water with high exothermic heat of reaction.</p> <p>Uses of Caustic soda (any 2)</p>	<p>1</p> <p>1</p> <p>1</p>



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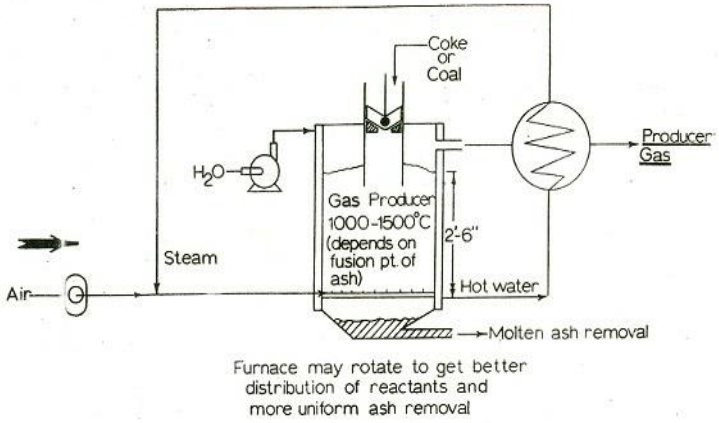
	1. Textile industry 2. Paper and Pulp 3. Alumina 4. Soap and detergent 5. Dyes	1
4	Attempt any four	16
a)	Ammonium Phosphate $\text{NH}_3 + \text{H}_3\text{PO}_4 \rightarrow \text{NH}_4\text{H}_2\text{PO}_4$ $\text{NH}_3 + \text{NH}_4\text{H}_2\text{PO}_4 \rightarrow (\text{NH}_4)_2\text{HPO}_4$ Ammonium sulfate $2\text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow (\text{NH}_4)_2\text{CO}_3$ $(\text{NH}_4)_2\text{CO}_3 + \text{CaSO}_4 \cdot 2\text{H}_2\text{O} \rightarrow (\text{NH}_4)_2\text{SO}_4 + \text{CaCO}_3 + 2\text{H}_2\text{O}$	2 2
b)	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 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	2 2



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	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.	
c)	<p>Composition of cement;(any 2)</p> <p>General Purpose – C3S (55%), C2S(19%), C3A(10%), C4AF(7%) other (9%)</p> <p>Moderate Heat - C3S (51%), C2S(24%), C3A(6%), C4AF(11%) other (8%)</p> <p>Early strength - C3S (56%), C2S(19%), C3A(10%), C4AF(7%) other (8%)</p> <p>Sulfate resistance - C3S (38%), C2S(43%), C3A(4%), C4AF(9%) other (6%)</p>	2 mark each for any two
d)	<p>Producer gas, 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.</p> <p>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.</p> 	2
e)	<p>Acetylene from CaC₂</p> <p>Raw materials: lime stone, coke, water</p>	1

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	<p>Chemical reactions:</p> $\text{CaO} + 3\text{C} \rightarrow \text{CaC}_2 + \text{CO}$ $\text{CaC}_2 + \text{H}_2\text{O} \longrightarrow \text{Ca(OH)}_2 + \text{CH}\equiv\text{CH}$ <p>Process Description:</p> <p>Calcium carbide is produced by heating lime and coke in an electric furnace at 2100 °C . Molten CaC₂ is solidified and cooled and ground under nitrogen</p> <p>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.</p> <p>Calcium hydroxide slurry containing 90% water is discharged. The gas is passes through a scrubber to remove impurities like NH₃, 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.</p> <p>In a dry process equal weights of the quantities H₂O and CaC₂ 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.</p> <p>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.</p>	<p>1</p> <p>2</p>
f)	PFD of Synthesis process for HCl	4



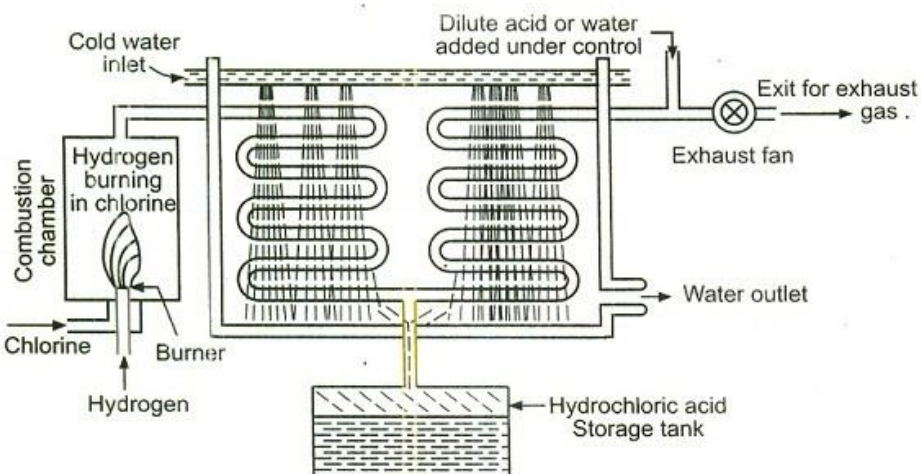
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5

Attempt any two

16

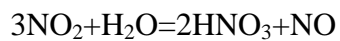
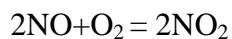
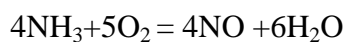
a)

Nitric Acid Production

Raw material

Ammonia, air, water

Reaction



2



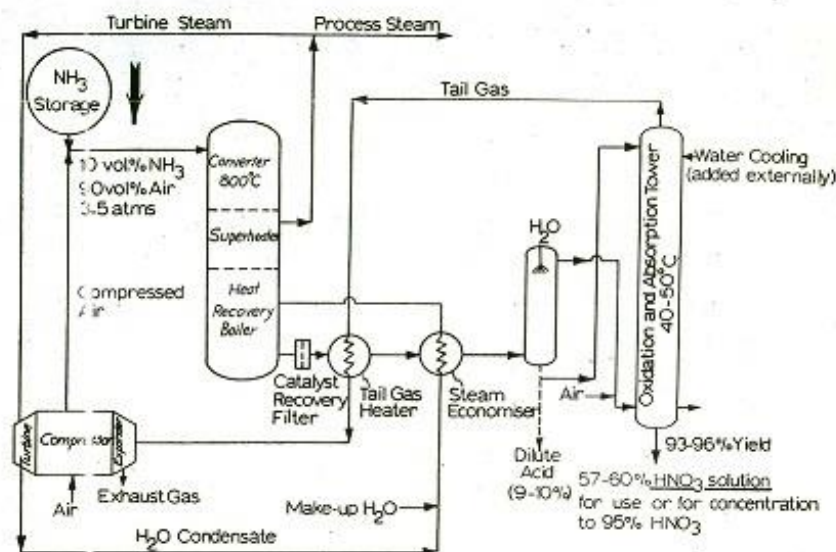
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Ammonia and air are compressed and send to the catalytic converter. Ammonia is oxidized and converted into nitric oxide. Large heat is evolved which can be utilized to run turbine by producing steam and gas expander. Both are connected to the compressor. Hence compressor does not require external energy source. NO_x gases after heat recovery is sent through cooler condenser where it is cooled by cooling tower water. Some part of acid is converted into liquid form. Both liquid and gas are sent 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.

3

b)

Phosphorous Production

Red Phosphorous

Raw material:

Phosphate rock, coke, sand

1



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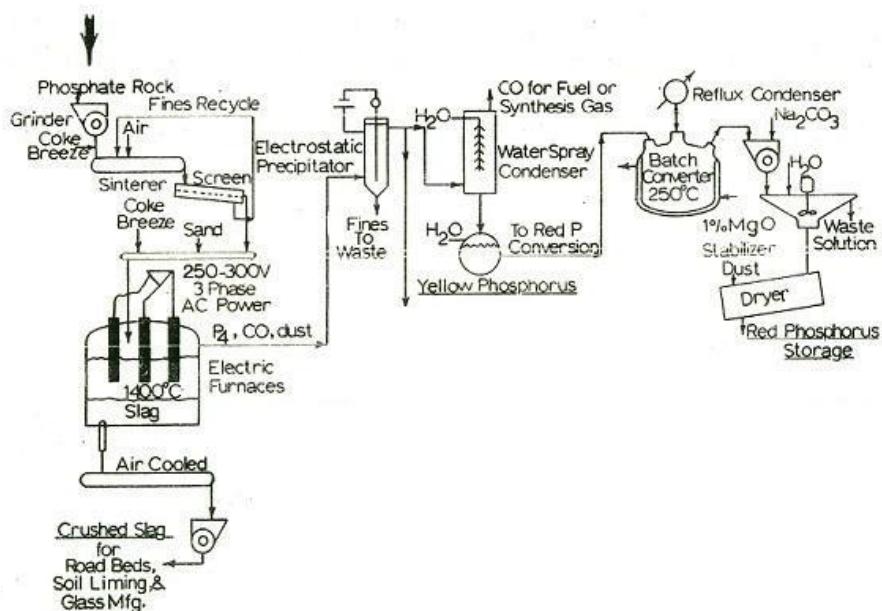
	<p>Reaction:</p> $2\text{Ca}_3(\text{PO}_4)_2 + 10\text{C} + 6\text{SiO}_2 = \text{P}_4 (\text{Yellow}) + 6 \text{CaSiO}_3 + 10\text{CO}$ <p>$\text{P}_4 (\text{Yellow}) + \text{heating} = \text{P}_4 (\text{Red})$</p> <p>Phosphate rock is ground, mixed with portion of coke requirement, then sintered into 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.</p> <p>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°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.</p> <p>Yellow phosphorus is converted into red phosphorous in covered retorts containing a reflux condenser to retain any evolved phosphorous vapors. The vessel is gradually heated and the contents melt and slowly change to red phosphorus. This mass is solidified when approximately 70% has been converted. Heat control is required as reaction is exothermic.</p>	3
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3

Uses of phosphorous;(any 2)

- Used to prepare
- phosphoric acid
- phosphate builders for detergents
- fertilizer
- animal feed
- pesticides
- gasoline lube oil additives
- fireworks
- flame retardants
- matches

½ mark
each

c)

Production of hydrogen:**Reaction:**

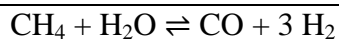
Rection

-1

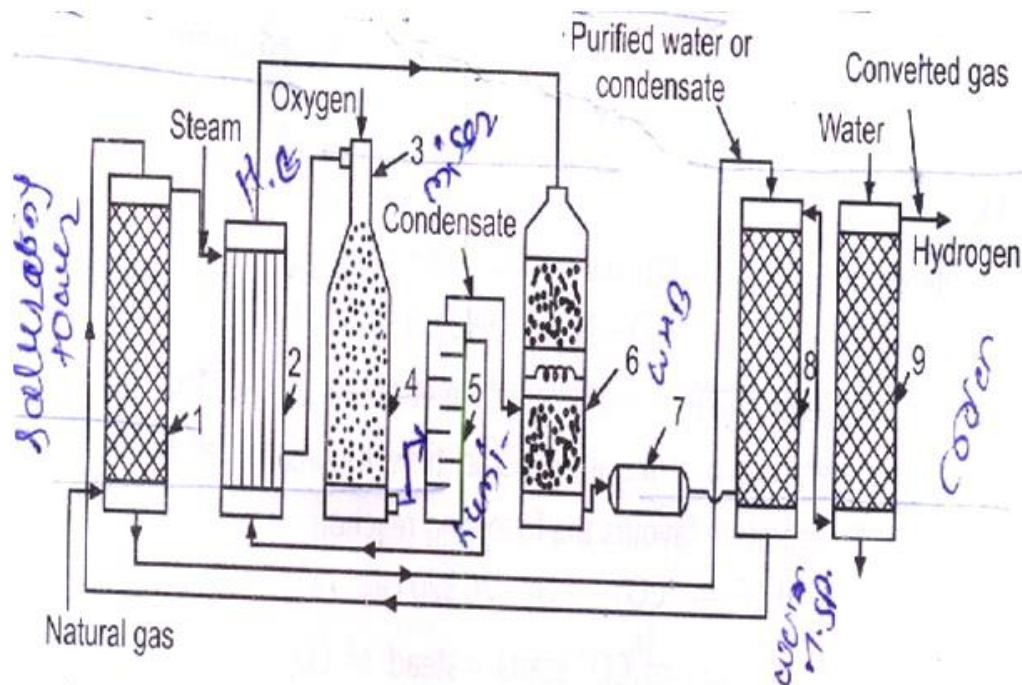
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Hydrogen from natural gas: Natural gas mainly methane is converted into hydrogen by mixing it with steam and passing the mixture over a catalyst nickel with alumina at 800-900°C . The natural gas is passes through a saturating tower saturated with water vap. At the exit steam is added and the steam gas mixture directed to the heat exchanger at 500-600°C .The gas mixture goes to mixture chamber where O₂ is introduced .This is entered at 450°C to methane convertor , After adding the catalyst at 800° C passed to humidifier where water vap. is added to reduce the temp. upto 750° C .The gases passes through heat exchanger which gives a heat to the gas going to the mixture chamber converted at 400° c and entered at carbon monoxide convertor. The gases are send to waste heat boiler, water tower spray and cooler for removal of CO₂.



Diagra

m-3

Process

-4



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6	Attempt any four	16
a)	<p>PFD –Ammonia production</p> <p>Yield: 85-90% Conversion: 8-30%</p>	4
b)	<p>Phosphoric acid by HCl Leaching: Phosphate rock is ground and HCl is added in it. Fumes of CO₂, HF and HCl are scrubbed for acid recovery. The mixture is fed to series of decanter and settlers and then to counter current solvent extraction operations. The solids underflow goes to 2-3 washing thickeners. Extraction of phosphoric acid and some free HCl is done in an battery of mixer –settlers with CaCl₂ retain in aqueous phase. The extract is passed through several more mixer settlers. Phosphoric acid is recovered in triple effect evaporator and CaCl₂ is separated from final settler.</p>	4
c)	<p>HCL by Salt and Sulphuric acid method:</p> $\begin{aligned} \text{NaCl} + \text{H}_2\text{SO}_4 &\longrightarrow \text{NaHSO}_4 + \text{HCl} \\ \text{NaHSO}_4 + \text{NaCl} &\longrightarrow \text{Na}_2\text{SO}_4 + \text{HCl} \end{aligned}$ <p>Both reactions involve the displacement of volatile acid from salt. The equilibrium can be displaced in desired direction by choice of condition i.e.</p>	1



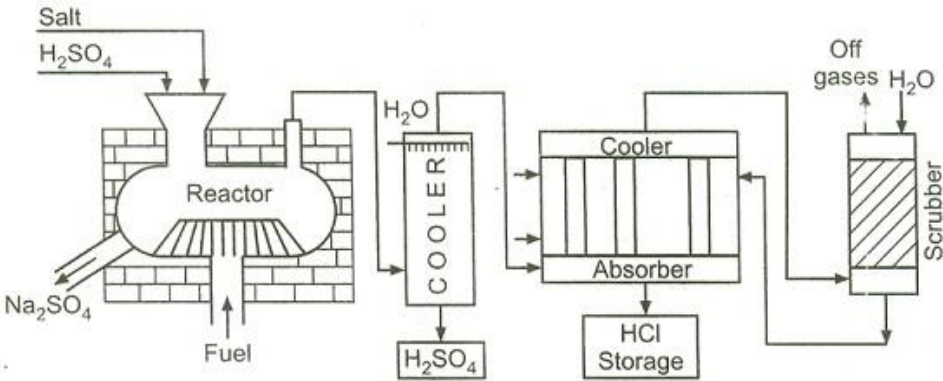
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	<p>promoting volatilization of HCl</p> <p>The high temperature process is superior to vacuum for this purpose. To promote reaction rate it is desirable to have temperature sufficiently high to keep at least one of the reacting component in liquid condition.</p> <p>There is no difficulty in first stage of decomposition but second stage required temperature of about 400 °C to liquefy NaHSO₄. The higher limit to temperature is the attack of corrosive relative mass on furnace.</p> <p>The product and unconverted H₂SO₄ is send to further processing in which there is recovery of H₂SO₄ by cooling and HCL is recovered as main product from absorber.</p>  <p>The diagram illustrates the chemical process for producing HCl. It starts with a Reactor where Salt and H₂SO₄ are fed in. Na₂SO₄ and Fuel are also added to the Reactor. The output from the Reactor goes to a COOLER, which produces H₂SO₄. The cooled H₂SO₄ then enters an Absorber, which produces HCl Storage. The output from the Absorber goes to a Scrubber, which produces Off gases and H₂O.</p>	2
d)	<p>Ammonia converter.</p> <p>The gases enter the converter at the base and pass upward round the chamber congaing catalyst Fe + Mo. Then they pass downward through the heat exchanger. The heat exchanger contains several coils of pipe, the mixture of gases get, heated by heat exchange and then passes downwards through the central chamber. It contains heating element. The mixture of gases passes up</p>	2



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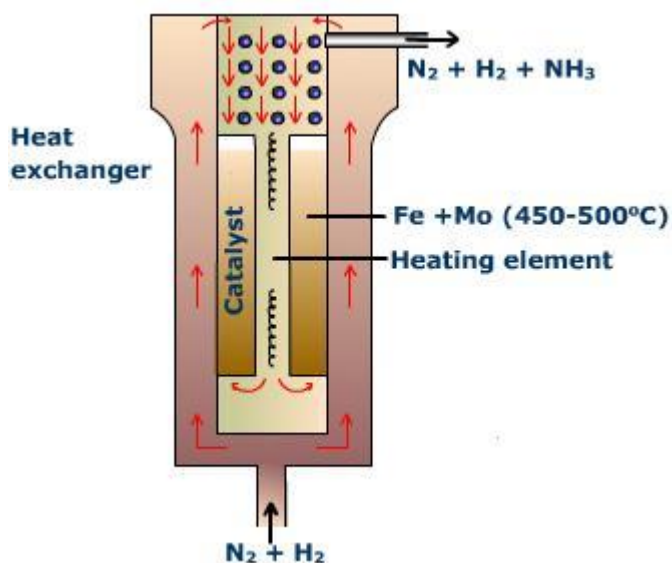
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through the contact chamber containing catalyst. Finally mixture of gases passes out through the coils of pipe of heat exchanger. It gives most of the heat to the fresh gases on their way to contact chamber. The proportion of ammonia in the coming out from converter is about 10 to 20 % and is remixed by cooling the mixture.





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e)	<p>PFD of Phosphoric Acid by sulfuric acid leaching</p> <p>4</p>
f)	<p>Ammoniation tower: Ammonia is absorbed in ammoniation tower in purified brine. Some amount of CO₂ is also absorbed here.</p> <p>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.</p> <p>2</p> <p>2</p>