higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

CHEMICAL TECHNOLOGY N6

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This marking guideline consists of 8 pages.

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QUESTION 1: DRYING

1.1
- Transfer of mass
- Transfer of heat (2)

1.2
- Diffusion coefficient
- Heat transfer coefficient (2)

1.3
- Tray dryer
- Scree-conveyor dryer
- Tower dryer or turbo dryer
- Rotary dryer
- Screw conveyor dryer
- Fluid-bed dryer
- Flash dryer (Any 6 × 1) (6)

1.4 1.4.1 Thin-film dryer (1)

1.4.2
A Vapour
B Feed
C Heating and crystallizing zone
D Slurry zone
E Free flowing powder zone
F Dry powder zone (6)

1.4.3 Thin-film dryers, competitive with spray dryers in some situations are capable of accepting liquid or slurry feed and produce a dry, free-flowing solid product. They are normally built in two sections, the first of which is a vertical agitated film evaporator-dryer. Here most of the liquid is removed from the feed, and partially wet solids are discharged to the second section in which the residual liquid content of the material from the first section is reduced to the desired value. The thermal efficiency of thin-film dryers is high, and there is little loss of solids, since little or no gas needs to be drawn through the unit. They are useful for removing and recovering solvents from solid products. They are relatively expensive and are somewhat limited in heat-transfer area. With both aqueous and solvent feeds the acceptable feed rate is usually between 100 and 200 kg/m^2-h. (10)

1.4.4
- Is it a batch or a continuous dryer?
- The dryer must operate reliably and safely.
- Is material agitated during drying or not?
- Is there direct contact (solids/hot air) or indirect contact (heat transfer through a metal wall)?
- Operation and maintenance cost should not be excessive.
- Energy consumption should be economical. (6)

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1.5
- Drying occurs during transportation.
- The rate of heat transfers and drying is rapid.
- Drying occurs for a short time at high temperatures.
- Wet feed enters at the paddle conveyor mixer.
- It is blended with dry material to make it free flowing.
- It then goes to the hammer mill where hot gases enter.
- Pulverised solids are carried to a long duct by a hot gas stream where drying occurs.
- A cyclone separates vapour and solids.
- The gas leaves through a vent.
- Solids pass through a star feeder to a solid divider.
- The divider sorts solids for refeeding. (Any 10 × 1) (10)

1.6 1.6.1
- High thermal efficiency.
- Little loss of solids because little or no gas is drawn through the unit.
- Useful in removing and recovering solvents from solid products. (3)

1.6.2
- Can handle a variety of solids continuously
- Cost is reasonable
- Steam economy is high
- Coarse granular, flaky or fibrous material can be dried without any pre-treatment and without loss of material through the screen. (4)

[50]

QUESTION 2: CRYSTALLISATION

2.1 2.1.1 Initial breeding is when seeds usually carry many small crystals✓ on their surfaces which were formed during the drying✓ and storage of the seeds after their own manufacture.✓ The small crystals soon wash off✓ and subsequently grow in the supersaturation.✓ (5)

Veiled growth occurs at moderate supersaturations.✓ It is the result of the occlusion of the mother liquor✓ into the crystal face,✓ giving a milky surface✓ and an impure product.✓ The cause of the veiled growth is too rapid crystal growth,✓ which traps mother liquor in the crystal faces.✓ (6)

2.1.2 It can be prevented by curing the seed crystal before using,✓ either by contact with a undersaturated solution or solvent✓ or by a preliminary growth in a stagnant supersaturated solution.✓ (3)

2.1.3
- Growing crystals at supersaturations
- Well-designed and operated pumps and agitators (2)

2.2 2.2.1 The rate of nucleation is the number of new particles formed✓ per unit of time✓ per unit of volume✓ of magma or solids-free mother liquor.✓ (4)

2.2.2 A small crystal can be in equilibrium✓ with a supersaturated solution.✓ Such an equilibrium is unstable✓ because if a large crystal is also present in the solution, the smaller crystal will dissolve✓ and the larger one will grow until the small crystal disappears.✓ (5)

2.3 In many industrial crystallisation processes, the crystal and mother liquor are in contact long enough to reach equilibrium and the mother liquor is saturated at the final temperature of the process. The yield of the process can then be calculated from the concentration of the original solution and the solubility at the final temperature.

When the rate of crystal growth is low, considerable time is required to reach equilibrium. In such a situation, the final mother liquor may retain appreciable super saturation and the actual yield will be less than that calculated from the solubility curve.

Crystallisers in which the crystals and mother liquor are not in equilibrium are called class I systems, and those in which the mother liquor is assumed to be saturated are called class II systems.

If the crystals are anhydrous, calculation of the yield is simple, as the solid phase contains no solvent. When the crop contains water of crystallisation, account must be taken of the water accompanying the crystals. The key to calculation of yields of hydrated solutes is to express all masses and concentrations in terms of hydrated salts and free water. (10)
[35]

QUESTION 3: HEAT TRANSFER

3.1 The instantaneous rays of heat transfer through a homogenous body✓ by conduction,✓ is directly proportional to the temperature difference driving force (t)✓ across the body and the cross-sectional area (A) of the body through which the heat flows.✓ The rate of heat transfer is inversely proportional✓ to the length of the path (x) along which the heat flows.✓ (6)

3.2 3.2.1 The fraction of incident radiation✓ which is absorbed by a material.✓ (2)

3.2.2 The total radiant energy emitted✓ from a unit area of a body✓ in a unit time,✓ divided by the total radiant energy emitted from a unit time from a unit area of a black body✓ at the same temperature.✓ (5)

3.2.3 A body which absorbs all the radiant energy on its surface✓ and reflects and transmits none.✓ (2)

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3.3
- Spray ponds
- Cooling tower
- Fractionation tower
- Steam strippers
- Absorbers (5)

3.4 3.4.1
- Heat transfer involves the flow of heat from one fluid through a solid retaining wall into another fluid.✓
- The resistances to be overcome are the two fluid-film resistances✓ and the solid-wall resistance.✓
- The total flow of heat is proportional to the heat-transfer area✓ and to the overall temperature difference.✓ (5)

3.4.2
- If the temperature difference between the heat source and a boiling liquid becomes sufficiently high✓ the surface of the heat source becomes covered with a film of vapour.✓
- This film has a higher resistance to heat transfer than the liquid film.✓
- Thus the flow of heat can be reduced by the use of too high a temperature difference.✓
- The temperature difference above which the individual heat transfer coefficient starts to decrease markedly✓ through the formation of an insulating-vapour film is known as the critical temperature difference.✓ (6)

3.5 $\frac{\Delta t_{in}}{\Delta t_{out}} = \frac{86}{33} > 2$✓

∴ $\Delta t_{log\ mean}$ must be used

$$\Delta t_{log\ mean} = \frac{\Delta t_2 - \Delta t_1}{2.3 \log \frac{\Delta t_2}{\Delta t_1}}$$✓

$$= \frac{86 - 33}{2.3 \log \frac{86}{33}}$$✓

$$= 55{,}40\ °C$$✓

$A^1{}_f$ (water film) $= \pi(45{,}5 \times 10^{-3}) \times 3{,}5$✓
$= 0{,}495\ m^2$✓

$A^{11}{}_f$ (steam film) $= \pi(45{,}5 + 4{,}2 \times 2)\ 10^{-3} \times 3{,}5$✓
$= 0{,}593\ m^2$✓

$$A_w = \frac{0{,}495 + 0{,}593}{2}$$✓
$= 0{,}544\ m^2$✓

$$\frac{1}{UA} = \frac{1}{h^1 Af} + \frac{1}{h^{11} A_f} + \frac{X_w}{KA_w}$$

$$= \frac{1}{2960 \times 0,495}\checkmark + \frac{1}{12\,340 \times 0,593}\checkmark + \frac{4,2 \times 10^{-3}}{55 \times 0,544}\checkmark$$

$$= 9,5953 \times 10^{-4}\ KW^{-1}\checkmark$$

UA = 1 042, 177 W.K-1✓
= 1 042, 177 × 55,40✓
= 57736,6 J/S ✓

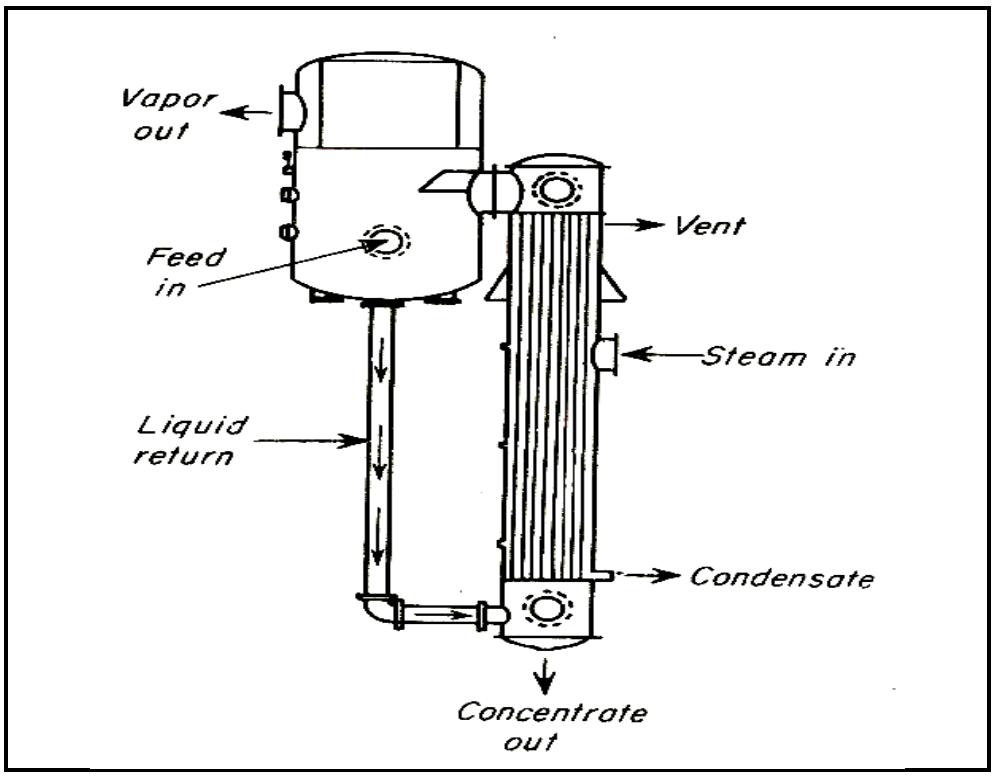
$$Q = \frac{57\,736,6 \times 3\,600}{1000}\checkmark$$

= 207 851,76 KJ✓ (19)
[50]

QUESTION 4: EVAPORATION

4.1 Evaporation is conducted by vaporising a portion of the solvent✓ to produce a concentrated solution of thick liquor.✓ It differs from distillation in that the vapour usually is a single component and even when the vapour is a mixture,✓ no attempt is made in the evaporation step to separate the vapour into fractions.✓ It differs from crystallisation in that emphasis is placed on concentrating a solution✓ rather than forming and building crystals.✓ (6)

4.2 4.2.1



(7)

4.2.2 Diluted feed, often at room temperature, enters and mixes with liquid from the separator.✓ The mixture enters the bottom of the tube on the outside of which the steam is condensing.✓ For a short time, the feed flows upwards in the tubes receiving heat from the steam.✓ Bubbles then form in the liquid as boiling begins, increasing the linear velocity and rate of heat transfers.✓ Near the top, bubbles grow rapidly.✓ Bubbles of vapour alternating with slugs of liquid rise and emerge at high velocity from the top.✓ From the tubes, the mixture enters the separator.✓ Because the diameter of the separator is larger than that of the exchanger,✓ the linear velocity is greatly reduced.✓ To further eliminate the liquid droplets, the vapour impinges on and passes a set of baffle plates before leaving the evaporator.✓ (10)

[23]

QUESTION 5: HUMIDIFICATION AND DE-HUMIDIFICATION

5.1 This kind of tower depends on the chimney effect✓ produced by the presence of air in the tower and vapour of higher temperature✓ and therefore of lower density than the surrounding atmosphere.✓ Thus, atmospheric conditions,✓ temperature and the quantity of the water✓ will exert an important effect on the operation of the tower.✓ It will influence the quantity of the air drawn through the tower✓ as well as the velocities and flow patterns✓ and the transfer coefficients between gas and liquid.✓ It is, therefore, important when designing a tower so that the resistance to flow of air is low.✓ (10)

5.2 5.2.1 Cross flow tower✓✓ (2)

5.2.2 In a cross flow tower, which is rectangular in cross section,✓ air passes horizontally through the inclined beds of packing or fill,✓ while water flows downward.✓ Slanted louvers prevent the escape of water drops to the outside✓ and angled baffles called drift eliminators capture most of the droplets that are entrained in the exit air.✓ Air is drawn through the tower by a propeller-type fan with several blades.✓ In large units, the pitch of the blades can be adjusted to vary the flow of air.✓ The fan is often located at the throat of a venturi-shaped✓ cylinder that promotes smooth flow of air to the fan and gives some pressure recovery in the expanding section.✓ The cylinder also discharges the moist air further above ground level,✓ which decreases the chance of recirculation to the air inlet.✓ This type of pressure recovery cylinder is mainly used with large cooling towers.✓ (12)

5.3 P_a = 60 mm.Hg✓
P = 101,3 kPa = 760 mm.Hg✓

$H_a = \frac{18\ P_a}{29\ (P - Pa)}$✓
$= \frac{18\ (60)}{29\ (760 - 60)}$✓ = 0,053 kg water per kg dry air✓✓
Mass of air = 15 + (1,88 × H_a)✓
= 15 + (1,88 × 0,053)✓
= 15,099 kg dry air✓✓

C_s = 1 + (1,88 × H_a)✓
= 1 + (1,88 × 0,053)✓
= 1,099 kJ/kg.K✓✓

Q = 1,099 × 15,099✓ × (45 – 40)✓
= 82,969 kJ✓✓ (18)
[42]

TOTAL: 200

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