GPAT Pharmaceutics

Sample Paper – 1

Duration: 36 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **25** Multiple Choice Questions (Single Correct Answer), modelled on the Pharmaceutics portion of **GPAT** entrance.
- Each correct answer carries **+4 marks**. There is **a penalty of −1 mark** for each incorrect answer. Unattempted questions carry no marks.
- Only **one** option is correct per question.
- Syllabus: **GPAT Pharmaceutics — Biopharmaceutics, Physical Pharmacy, Dispersed Systems, Dosage Forms, Drug Delivery.**
- Personal calculators, mobile phones, and electronic gadgets are strictly prohibited. A simple on-screen calculator is provided in the CBT interface; rough sheets are supplied at the centre.

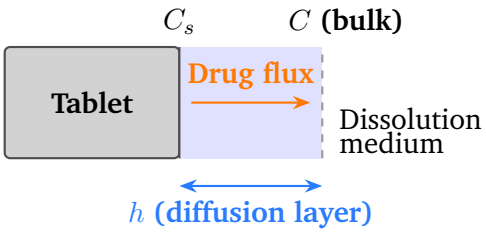
Q1. According to the Biopharmaceutics Classification System (BCS), which class contains drugs that satisfy *both* of the following criteria simultaneously: aqueous solubility $>$ Dose/250 mL (measured across pH 1–7.5) *and* apparent intestinal permeability $P_{\text{app}} > 10^{-6}$ cm/s (Caco-2)?

(A) Class II — low solubility, high permeability
(B) Class III — high solubility, low permeability
(C) Class I — high solubility, high permeability
(D) Class IV — low solubility, low permeability

Q2. The Noyes-Whitney equation for dissolution rate is:

$$\frac{dM}{dt} = \frac{DA(C_s - C)}{h}$$

The figure below shows a dissolving tablet with surface concentration C_s, bulk concentration C, and diffusion-layer thickness h.



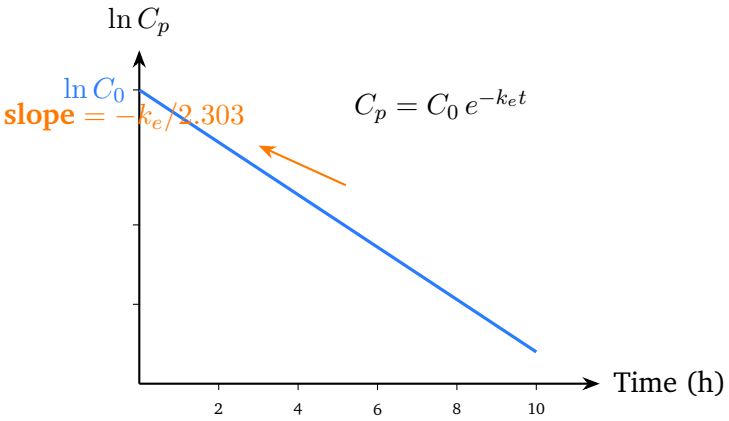
If the surface area A of the dissolving tablet is **doubled** while D, C_s, C, and h remain constant, the dissolution rate dM/dt will:

(A) Decrease to half its original value
(B) Double (increase two-fold)
(C) Remain unchanged
(D) Increase four-fold

Q3. A drug is completely absorbed from the gastrointestinal tract ($f_{\text{abs}} = 1.0$) but undergoes extensive hepatic first-pass metabolism. The hepatic extraction ratio $E_H = 0.70$. Using the relationship $F = f_{\text{abs}} \times (1 - E_H)$, the oral systemic bioavailability F is:

(A) 30%
(B) 70%
(C) 50%
(D) 100%

Q4. A drug follows one-compartment open model pharmacokinetics after intravenous bolus administration. The semilog plot of plasma concentration C_p versus time (shown below) yields a straight line with intercept C_0 and slope $= -k_e/2.303$.



Given $C_0 = 50\,\text{mg/L}$ and $k_e = 0.1\,\text{h}^{-1}$, what is C_p at $t = 6.93\,\text{h}$? (*Hint*: $\ln 2 = 0.693$)

(A) 12.5 mg/L
(B) 43.6 mg/L
(C) 35.4 mg/L
(D) 25.0 mg/L

Q5. Following an intravenous bolus dose of 500 mg, the initial plasma concentration C_0 is measured as 10 mg/L. Using $V_d = \text{Dose}/C_0$, calculate the apparent volume of distribution.

(A) 25 L
(B) 50 L
(C) 100 L
(D) 5 L

Q6. A drug's plasma concentration data yield an elimination rate constant $k_e = 0.0462\,\text{h}^{-1}$. Using the relationship $t_{1/2} = 0.693/k_e$, calculate the biological half-life.

(A) 10 h
(B) 20 h
(C) 15 h
(D) 30 h

Q7. Ibuprofen is a weak acid with $\mathrm{p}K_a = 4.4$. According to the Henderson-Hasselbalch equation, ionisation of the carboxylic acid group increases aqueous solubility. At which pH will ibuprofen exhibit the **greater** aqueous solubility?

(A) pH 7.4
(B) pH 2.0
(C) Solubility is equal at both pH values because only the unionised species dissolves
(D) pH has no effect on ibuprofen solubility; only temperature matters

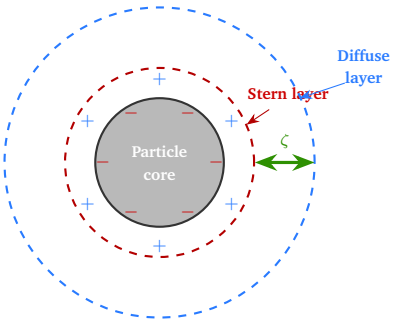
Q8. A weak base has $\mathrm{p}K_a = 8.0$. The fraction ionised is given by $f_{\text{ionised}} = 1/\left(1 + 10^{(\mathrm{pH} - \mathrm{p}K_a)}\right)$. Which statement **correctly** describes the ionisation state of this drug at gastric pH 2.0?

(A) The drug is predominantly unionised ($> 99\%$ free base) at pH 2.0
(B) The drug is exactly 50% ionised at pH 2.0 because equilibrium is established
(C) Approximately 1% of the drug is ionised at pH 2.0
(D) The drug is essentially completely ionised (ionised fraction $> 99.9999\%$) at gastric pH 2.0

Q9. A drug substance exists in two polymorphic forms: metastable Form II and thermodynamically stable Form I. In aqueous dissolution testing at room temperature, Form II dissolves significantly faster than Form I. Which statement **best** explains this observation?

(A) Form II has a lower melting point than Form I and therefore liquefies more readily during dissolution
(B) Form II possesses higher lattice free energy than Form I, resulting in greater intrinsic solubility and a faster dissolution rate
(C) Form I and Form II have identical intrinsic solubility; any difference in dissolution rate arises solely from differences in particle size
(D) Form II is thermodynamically more stable, which lowers the activation energy for dissolution

Q10. The diagram below shows a charged colloidal particle surrounded by its electrical double layer.



Zeta potential (ζ) is a measure of the effective charge at the slipping plane. Which of the following values indicates a **stable** colloidal dispersion?

(A) $-35\,\text{mV}$
(B) $-10\,\text{mV}$
(C) $+5\,\text{mV}$
(D) $0\,\text{mV}$

Q11. A formulator needs to produce an oil-in-water (O/W) emulsion with a required HLB of 12. Two surfactants are available: Span 80 (HLB $= 4.3$) and Tween 80 (HLB $= 15.0$). Using the weighted-average HLB rule, what **weight fraction** of Tween 80 must be used in the blend?

(A) 51%
(B) 60%
(C) 72%
(D) 85%

Q12. According to Stokes' law, the sedimentation velocity of a spherical particle in a viscous medium is:

$$v = \frac{2\,r^2(\rho_p - \rho_m)\,g}{9\,\eta}$$

If the radius r of the dispersed particles is **doubled** while all other parameters (ρ_p, ρ_m, g, η) remain constant, the sedimentation rate changes by a factor of:

(A) $\frac{1}{2}$ (halved)
(B) 2 (doubled)
(C) 3 (tripled)
(D) 4 (quadrupled)

Q13. An ionic surfactant solution is cooled below its Krafft temperature. Which of the following **correctly** describes the consequence for micelle formation?

(A) Micelles become smaller but persist in the aqueous phase
(B) Micelle formation ceases because the surfactant's aqueous solubility falls below the critical micelle concentration (CMC)
(C) The CMC value increases proportionally with decreasing temperature, allowing new micelles to reform
(D) Micelle formation is enhanced because reduced thermal agitation promotes hydrophobic self-assembly

Q14. In wet granulation, a binder (e.g., povidone/PVP or hydroxypropyl methylcellulose/HPMC) is dissolved in the granulating fluid or blended dry before moistening. What is the **primary** function of the binder in this process?

(A) To hold primary drug and excipient particles together by forming solid bridges on drying, creating mechanically strong, cohesive granules with improved compressibility
(B) To act as a glidant and reduce inter-particle friction during die filling
(C) To promote rapid disintegration of the finished tablet in gastrointestinal fluid
(D) To prevent moisture uptake by the formulation during long-term storage

Q15. Hard gelatin capsule shells are manufactured to contain 12–15% moisture, which is essential for their mechanical properties. If the capsule shell moisture content falls **below 10%**, which consequence is most likely?

(A) The shell softens and becomes sticky, causing capsules to adhere to one another
(B) The shell dissolves prematurely on contact with saliva before swallowing
(C) The shell becomes brittle and prone to cracking or splitting during handling
(D) The fill material migrates through the shell wall due to reduced barrier integrity

Q16. A 2% w/v glucose solution is prepared for intravenous infusion. The sodium chloride equivalent (E value) of glucose is 0.18. Blood (and isotonic saline) is isotonic with 0.9% w/v NaCl. What concentration of NaCl must be **added** to the 2% w/v glucose solution to render it isotonic?

(A) 0.18% w/v
(B) 0.36% w/v
(C) 0.72% w/v
(D) 0.54% w/v

Q17. Hydrolysis of aspirin in dilute aqueous solution is experimentally observed to follow pseudo-first-order kinetics. Which statement **best** explains this behaviour?

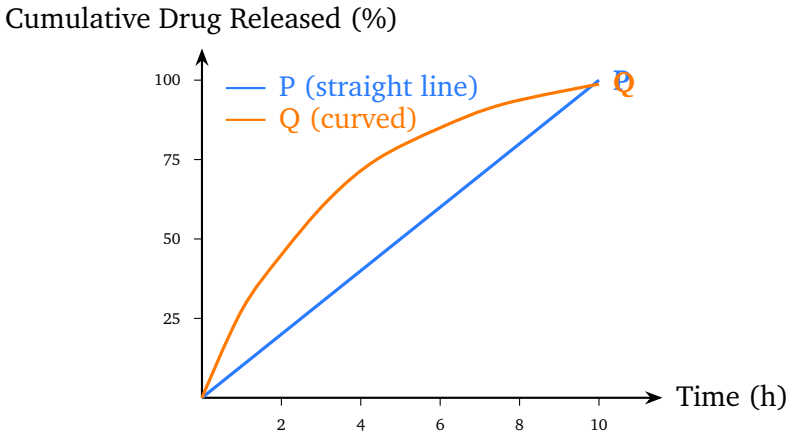
(A) Aspirin contains only a single hydrolysable ester bond; reaction order is determined solely by the number of susceptible bonds present
(B) Water is present in vast molar excess and its concentration remains essentially constant throughout the reaction, so the rate depends only on the aspirin concentration
(C) The transition state of aspirin hydrolysis involves only one aspirin molecule, making the mechanism inherently first-order by definition
(D) Because aspirin hydrolyses to exactly one primary product (salicylic acid), stoichiometry demands that the kinetics be first-order

Q18. A new tablet formulation contains a drug with a primary amine ($-NH_2$) functional group. During stability testing at elevated temperature and

humidity, brown discolouration and potency loss are observed. Which commonly used tablet excipient should be **avoided** in this formulation due to susceptibility to Maillard-type condensation?

(A) Lactose (spray-dried or anhydrous)
(B) Microcrystalline cellulose (MCC, Avicel)
(C) Colloidal silicon dioxide (Aerosil)
(D) Magnesium stearate

Q19. The figure below shows cumulative drug released (%) versus time for two controlled-release formulations, P and Q.



Which formulation provides a **constant rate** of drug release (zero-order kinetics)?

(A) Formulation Q, because concentration-dependent release is always zero-order at early time points
(B) Both P and Q, since both formulations ultimately deliver 100% of the drug
(C) Formulation P, whose cumulative drug release increases linearly with time
(D) Formulation Q, because a sigmoidal curved profile defines zero-order release

Q20. Hydrophilic HPMC matrix tablets are widely used for oral extended-release drug delivery. When the tablet contacts aqueous gastrointestinal

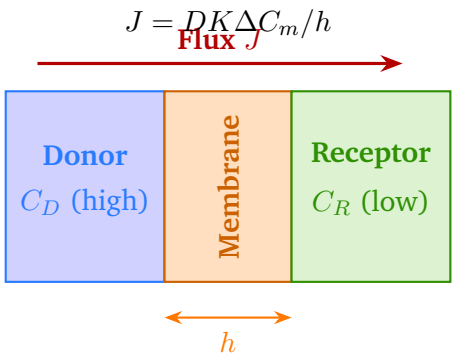
fluid, HPMC hydrates and swells to form a viscous gel layer. Which combination of mechanisms **best** describes drug release from this system?

(A) Osmotic pressure-driven pumping through a laser-drilled orifice and pore-channel formation by dissolved excipients
(B) Ion-exchange of drug with physiological cations and subsequent membrane rupture
(C) Enzymatic degradation of the HPMC polymer backbone and pH-triggered swelling
(D) Diffusion of drug molecules through the hydrated gel layer and simultaneous erosion of the gel front into the dissolution medium

Q21. Steady-state transdermal flux is described by Fick's first law:

$$J = \frac{D\,K\,\Delta C_m}{h}$$

where D is diffusivity in the membrane, K is the membrane/vehicle partition coefficient, ΔC_m is the concentration difference across the membrane, and h is membrane thickness. The diagram below illustrates a diffusion cell.



If the membrane thickness h is **doubled** (with D, K, and ΔC_m unchanged), what happens to the steady-state flux J?

(A) J is halved
(B) J is doubled
(C) J remains unchanged because the diffusivity compensates automatically
(D) J decreases to one-quarter of its original value

Q22. Which liposome preparation technique involves dissolving phospholipids in an organic solvent (e.g., chloroform), evaporating the solvent under reduced pressure on a rotary evaporator to deposit a thin dry lipid film on the flask wall, and then hydrating that film with an aqueous buffer to produce multilamellar vesicles (MLVs)?

(A) Solvent injection (ethanol injection) method
(B) Thin-film hydration (Bangham) method
(C) Reverse-phase evaporation (REV) method
(D) Detergent depletion (dialysis) method

Q23. For an inhaled drug aerosol designed to achieve systemic drug action via absorption across the alveolar epithelium, which particle size range expressed as mass median aerodynamic diameter (MMAD) is **optimal** for deposition in the deep lung (alveolar region)?

(A) MMAD 10–$20\,\mu$m
(B) MMAD 5–$10\,\mu$m
(C) MMAD 1–$5\,\mu$m
(D) MMAD $< 0.5\,\mu$m

Q24. The BP and USP friability test for uncoated tablets involves rotating a sample in a drum friabilator for 100 revolutions (approximately 4 minutes). What is the **maximum** acceptable percentage weight loss specified by both pharmacopoeias?

(A) $\leq 0.1\%$ weight loss
(B) $\leq 0.5\%$ weight loss
(C) $\leq 2.0\%$ weight loss
(D) $\leq 1.0\%$ weight loss

Q25. A strongly alkaline injectable formulation (pH > 9) containing a therapeutic protein is to be filled into glass containers. Which glass type is **required** by pharmacopoeial standards to minimise leaching of alkali ions and silica into the product?

(A) Type I borosilicate glass (highly resistant)
(B) Type II treated soda-lime glass
(C) Type III untreated soda-lime glass
(D) Type NP general-purpose soda-lime glass (non-parenteral)

Detailed Solutions

Q1.

Solution

Concept — BCS Classification: The Biopharmaceutics Classification System (BCS) categorises drugs by two parameters: aqueous solubility (relative to dose) and intestinal permeability. Class I satisfies *both* high-solubility AND high-permeability criteria simultaneously.

Step 1 — Identify the solubility criterion: High solubility is defined as: the highest dose strength dissolves in ≤ 250 mL water across pH 1–7.5, i.e., solubility $>$ Dose/250 mL. Only Classes I and III meet this criterion.

Step 2 — Apply the permeability criterion: High permeability is $P_{\text{app}} > 10^{-6}$ cm/s (Caco-2 assay), corresponding to $> 90\%$ oral absorption. Only Class I satisfies BOTH high solubility AND high permeability. Class IV has NEITHER criterion met.

Why other options are wrong:

- Option A: Class II — low solubility, high permeability (only one criterion met).
- Option B: Class III — high solubility but low permeability (only one criterion met).
- Option C: Class I — high solubility AND high permeability. **Correct.**
- Option D: Class IV — low solubility AND low permeability (neither criterion met).

Final Answer: Class I requires solubility $>$ Dose/250 mL AND $P_{\text{app}} > 10^{-6}$ cm/s $\Rightarrow$ C

Answer: (C) Go Back to Q1

Q2.

Solution

Concept — Noyes-Whitney Dissolution Equation: The Noyes-Whitney equation, $dM/dt = DA(C_s - C)/h$, shows that the dissolution rate is directly proportional to the surface area A of the dissolving solid. Doubling A while holding all other variables constant doubles the rate.

Step 1 — Identify variables and their relationships: $dM/dt \propto A$ (direct propor-

tionality). If $A \to 2A$, then $dM/dt \to 2 \times (dM/dt)_{\text{original}}$.

Step 2 — Calculate the new rate: New rate $= D \cdot (2A) \cdot (C_s - C)/h = 2 \times [DA(C_s - C)/h]$. The dissolution rate exactly doubles.

Why other options are wrong:

- Option A: Halving would result from halving A, not doubling it.
- Option B: Doubling A doubles the rate. **Correct.**
- Option C: Rate is proportional to A; changing A always changes the rate.
- Option D: Quadrupling would require A to increase 4-fold, or r to double (since $A \propto r^2$ for spheres).

Final Answer: Dissolution rate doubles when surface area doubles $\Rightarrow$ B

Answer: (B) Go Back to Q2

Q3.

Solution

Concept — Oral Bioavailability and Hepatic First-Pass Extraction: Oral bioavailability F is reduced by both incomplete absorption and hepatic first-pass metabolism. The relationship is $F = f_{\text{abs}} \times (1 - E_H)$, where E_H is the hepatic extraction ratio (fraction extracted by the liver on first pass).

Step 1 — Insert given values: $f_{\text{abs}} = 1.0$ (complete absorption); $E_H = 0.70$ (70% extracted by liver).

Step 2 — Calculate F: $F = 1.0 \times (1 - 0.70) = 1.0 \times 0.30 = 0.30 = 30\%$. Only 30% of the administered dose reaches the systemic circulation.

Why other options are wrong:

- Option A: 30% is correct. **Correct.**
- Option B: 70% equals E_H (the extracted fraction), not the bioavailable fraction.
- Option C: 50% would arise only if $E_H = 0.50$.
- Option D: 100% is possible only with $E_H = 0$; any hepatic extraction reduces F.

Final Answer: $F = 1.0 \times (1 - 0.70) = 30\% \Rightarrow$ A

Answer: (A) Go Back to Q3

Q4.

Solution

Concept — One-Compartment IV Bolus Pharmacokinetics: For a one-compartment IV bolus, plasma concentration declines monoexponentially: $C_p = C_0\, e^{-k_e t}$. On a semilog plot this appears as a straight line with slope $-k_e/2.303$. The time to reduce concentration by half is $t_{1/2} = 0.693/k_e$.

Step 1 — Identify the half-life: $t_{1/2} = 0.693/k_e = 0.693/0.1 = 6.93\,\text{h}$. Therefore, $t = 6.93\,\text{h}$ is exactly one half-life.

Step 2 — Calculate C_p at one half-life: $C_p = C_0 \times \frac{1}{2} = 50 \times 0.5 = 25\,\text{mg/L}$.
Verification: $C_p = 50\, e^{-0.1\times 6.93} = 50\, e^{-0.693} = 50 \times 0.500 = 25\,\text{mg/L}$.

Why other options are wrong:

- Option A: 12.5 mg/L corresponds to C_p after two half-lives ($t = 13.86\,\text{h}$).
- Option B: 43.6 mg/L corresponds to approximately $0.1\,h^{-1} \times 1\,\text{h}$ decay ($\approx C_0 e^{-0.1}$), not 6.93 h.
- Option C: 35.4 mg/L has no pharmacokinetic basis for this problem.
- Option D: 25.0 mg/L is exactly $C_0/2$ after one half-life (6.93 h). **Correct.**

Final Answer: $C_p(6.93\ \text{h}) = 50 \times e^{-0.693} = 25\,\text{mg/L} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — Apparent Volume of Distribution: The apparent volume of distribution V_d is a proportionality constant relating total drug in the body to the measured plasma concentration. After IV bolus, $V_d = \text{Dose}/C_0$ where C_0 is the zero-time (extrapolated) plasma concentration.

Step 1 — Identify values: Dose $= 500\,\text{mg}$; $C_0 = 10\,\text{mg/L}$.

Step 2 — Calculate V_d: $V_d = 500\,\text{mg}/10\,\text{mg}\,\text{L}^{-1} = 50\,\text{L}$.

Why other options are wrong:

- Option A: 25 L would imply $C_0 = 500/25 = 20\,\text{mg/L}$, not 10 mg/L.
- Option B: 50 L is correct. **Correct.**
- Option C: 100 L would imply $C_0 = 5\,\text{mg/L}$, not 10 mg/L.
- Option D: 5 L would imply $C_0 = 100\,\text{mg/L}$, inconsistent with the data.

Final Answer: $V_d = 500\,\text{mg}/10\,\text{mg/L} = 50\,\text{L} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

Concept — Biological Half-Life: The elimination half-life $t_{1/2}$ is the time for plasma drug concentration to fall to half its current value. It is related to the first-order elimination rate constant k_e by $t_{1/2} = 0.693/k_e$ (where 0.693 $= \ln 2$).

Step 1 — Insert the given value: $k_e = 0.0462\,\text{h}^{-1}$.

Step 2 — Compute $t_{1/2}$: $t_{1/2} = 0.693/0.0462 = 15.0\,\text{h}$.

Why other options are wrong:

- Option A: 10 h would require $k_e = 0.0693\,\text{h}^{-1}$, which is 1.5× larger.
- Option B: 20 h would require $k_e = 0.0347\,\text{h}^{-1}$.
- Option C: 15 h is correct. **Correct.**
- Option D: 30 h would require $k_e = 0.0231\,\text{h}^{-1}$, half the given value.

Final Answer: $t_{1/2} = 0.693/0.0462 = 15\,\text{h} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept — pH-Solubility Profile of a Weak Acid: For weak acids, increasing pH above the $\text{p}K_a$ progressively ionises the molecule. The ionised form is far more water-soluble than the unionised form. Total solubility $S_T = S_0(1 + 10^{\text{pH}-\text{p}K_a})$ for a monoprotic acid.

Step 1 — Calculate ionised fraction at each pH: At pH 7.4: $\alpha_{\text{ion}} = 10^{(7.4-4.4)}/(1+10^{3.0}) = 10^3/(1+10^3) \approx 99.9\%$.
At pH 2.0: $\alpha_{\text{ion}} = 10^{(2.0-4.4)}/(1+10^{-2.4}) \approx 0.4\%$ (essentially unionised).

Step 2 — Compare solubility: At pH 7.4, ibuprofen is ∼999× more ionised than at pH 2.0. The ionised carboxylate anion is highly hydrophilic, dramatically increasing total aqueous solubility.

Why other options are wrong:

- Option A: pH 7.4 gives far greater solubility due to extensive ionisation. **Correct.**
- Option B: At pH 2.0 (well below $\mathrm{p}K_a = 4.4$) ibuprofen is unionised and sparingly soluble.
- Option C: Solubility is strongly pH-dependent for ionisable drugs; they are not equal.
- Option D: pH is the dominant driver of solubility for ionisable drugs; temperature is secondary.

Final Answer: Ibuprofen is $\sim$1000$\times$ more ionised at pH 7.4 $\Rightarrow$ A

Answer: (A) Go Back to Q7

Q8.

Solution

Concept — Ionisation of Weak Bases at Low pH: For a weak base with $\mathrm{p}K_a$, the fraction ionised (protonated cation) is: $f_{\text{ion}} = 1/(1 + 10^{\mathrm{pH}-\mathrm{p}K_a})$. At pH values well below $\mathrm{p}K_a$, the exponent $(\mathrm{pH} - \mathrm{p}K_a)$ is a large negative number, making $10^{\mathrm{pH}-\mathrm{p}K_a} \ll 1$, so $f_{\text{ion}} \to 1$ (completely ionised).

Step 1 — Compute the exponent at pH 2.0: $\mathrm{pH} - \mathrm{p}K_a = 2.0 - 8.0 = -6.0$. Therefore $10^{-6.0} = 1.0 \times 10^{-6}$.

Step 2 — Calculate the ionised fraction: $f_{\text{ion}} = 1/(1 + 10^{-6}) = 1/(1.000001) \approx 0.999999 = 99.9999\%$ ionised.

Why other options are wrong:

- Option A: Predominantly unionised is incorrect; at pH far below $\mathrm{p}K_a$, the base is protonated (ionised).
- Option B: 50% ionised occurs at pH $= \mathrm{p}K_a$ (pH 8.0), not pH 2.0.
- Option C: $\sim$1% ionised is wrong; it is $> 99.9999\%$ ionised.
- Option D: $> 99.9999\%$ ionised. **Correct.**

Final Answer: At gastric pH 2.0, the weak base ($\mathrm{p}K_a = 8$) is essentially 100% ionised $\Rightarrow$ D

Answer: (D) Go Back to Q8

Q9.

Solution

Concept — Polymorphism and Thermodynamic Stability: Polymorphs are different crystal forms of the same drug with distinct crystal lattice arrangements. The thermodynamically stable polymorph (Form I) occupies the lowest free-energy state. The metastable polymorph (Form II) has higher lattice free energy, which translates directly to greater intrinsic solubility (C_s) and faster dissolution rate, as described by the van't Hoff and Noyes-Whitney relationships.

Step 1 — Relate free energy to solubility: $\Delta G_{\text{lattice}} \propto \ln(C_s)$. Higher free energy (Form II) $\Rightarrow$ higher C_s $\Rightarrow$ greater driving force for dissolution.

Step 2 — Connect to dissolution rate: By the Noyes-Whitney equation, $dM/dt \propto (C_s - C)$. With higher C_s for Form II, the concentration gradient driving dissolution is larger, giving a faster dissolution rate.

Why other options are wrong:

- Option A: Melting point is related to lattice energy but it is not the direct driver of dissolution rate in solution; the free energy–solubility relationship is the correct mechanistic explanation.
- Option B: Higher lattice free energy in Form II gives higher intrinsic solubility and faster dissolution. **Correct.**
- Option C: Polymorphs have different intrinsic solubilities; particle size effects are superimposed on but do not negate the intrinsic solubility difference.
- Option D: Form II is metastable, not thermodynamically more stable; it dissolves faster precisely because it is less stable (higher free energy).

Final Answer: Form II has higher lattice free energy $\Rightarrow$ higher C_s $\Rightarrow$ faster dissolution $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

Concept — Zeta Potential and Colloidal Stability: Zeta potential (ζ) measures the electrical potential at the slipping (shear) plane surrounding a colloidal particle. It reflects the magnitude of inter-particle electrostatic repulsion. The conventional threshold for colloidal stability is $|\zeta| \geq 30$ mV; values below ± 15 mV indicate approaching instability and aggregation.

Step 1 — Apply the stability criterion: $|\zeta|$ must be ≥ 30 mV for adequate electrostatic repulsion to keep particles dispersed. Values $\leq \pm 15$ mV indicate insufficient repulsive forces.

Step 2 — Evaluate each option: $|-35\,\text{mV}| = 35\,\text{mV} \geq 30\,\text{mV} \Rightarrow$ stable. All other options are ≤ 15 mV, far below the stability threshold.

Why other options are wrong:

- Option A: -35 mV satisfies $|\zeta| \geq 30$ mV. **Correct; stable dispersion.**
- Option B: -10 mV ($|\zeta| < 15$ mV) — insufficient repulsion; dispersion is unstable.
- Option C: $+5$ mV ($|\zeta| < 15$ mV) — approaching isoelectric point; strongly unstable.
- Option D: 0 mV — isoelectric point; maximum aggregation tendency, completely unstable.

Final Answer: $|\zeta| = 35\,\text{mV} \geq 30\,\text{mV}$ indicates a stable colloid $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept — HLB Blending Rule: The required HLB for an emulsifier blend can be matched using the weighted-average rule: $\text{HLB}_{\text{blend}} = x_1\,\text{HLB}_1 + x_2\,\text{HLB}_2$, where $x_1 + x_2 = 1$ are weight fractions. This allows calculation of the proportion of each surfactant.

Step 1 — Set up the equation: Let x_T = weight fraction of Tween 80 (HLB 15.0), then $(1 - x_T)$ = fraction of Span 80 (HLB 4.3). Required HLB = 12.

$$12 = 4.3\,(1 - x_T) + 15.0\,x_T$$

Step 2 — Solve for x_T: $12 = 4.3 - 4.3\,x_T + 15.0\,x_T = 4.3 + 10.7\,x_T$
$10.7\,x_T = 7.7 \Rightarrow x_T = 7.7/10.7 \approx 0.720 = 72\%$.

Why other options are wrong:

- Option A: 51% Tween 80 gives HLB $= 4.3 \times 0.49 + 15.0 \times 0.51 = 9.75$, not 12.
- Option B: 60% Tween 80 gives HLB $= 4.3 \times 0.40 + 15.0 \times 0.60 = 10.72$, not 12.
- Option C: 72% Tween 80 gives HLB ≈ 12.0. **Correct.**

- Option D: 85% Tween 80 gives HLB $= 4.3 \times 0.15 + 15.0 \times 0.85 = 13.40$, not 12.

Final Answer: $x_T = 7.7/10.7 \approx 72\%$ Tween 80 $\Rightarrow$ C

Answer: (C) Go Back to Q11

Q12.

Solution

Concept — Stokes' Law and Sedimentation Rate: Stokes' law gives the terminal settling velocity of a spherical particle: $v = 2r^2(\rho_p - \rho_m)g/(9\eta)$. The velocity is proportional to the *square* of the particle radius ($v \propto r^2$), so doubling r quadruples v.

Step 1 — Identify the proportionality: $v \propto r^2$. If $r \to 2r$, then $v \to (2r)^2 \times$ constant $= 4r^2 \times$ constant.

Step 2 — Compute the ratio: $v_{\text{new}}/v_{\text{old}} = (2r)^2/r^2 = 4$. Sedimentation rate increases 4-fold.

Why other options are wrong:

- Option A: Halving occurs when r is reduced by a factor of $\sqrt{2}$, not doubled.
- Option B: Doubling the rate would result from doubling $(\rho_p - \rho_m)$ or g/η, not from doubling r.
- Option C: 3-fold increase has no basis in Stokes' law; the exponent of r is 2, not 1.5.
- Option D: 4-fold increase follows from $v \propto r^2$ when r is doubled. **Correct.**

Final Answer: $v \propto r^2$; doubling r gives $v_{\text{new}} = 4\,v_{\text{old}} \Rightarrow$ D

Answer: (D) Go Back to Q12

Q13.

Solution

Concept — Krafft Temperature and Micelle Formation: The Krafft temperature (T_K) is the minimum temperature at which a surfactant's aqueous solubility equals its CMC. Above T_K, the surfactant dissolves sufficiently to exceed the CMC, enabling micelle formation. Below T_K, the surfactant's solubility is *less* than the CMC; the surfactant precipitates or remains as monomers but cannot form micelles.

Step 1 — Understand the Krafft point: At $T < T_K$: solubility $<$ CMC. Even if some surfactant is dissolved, the concentration is insufficient to reach the CMC threshold for micelle self-assembly.

Step 2 — Predict the consequence: Micelles cannot form because the dissolved monomer concentration never reaches the CMC. The bulk of surfactant remains as a crystalline hydrate or precipitate.

Why other options are wrong:

- Option A: Micelles do not persist below T_K; they dissociate or cannot form.
- Option B: Micelle formation ceases as solubility falls below CMC. **Correct.**
- Option C: The CMC does not increase proportionally; temperature affects solubility, not CMC in a simple linear manner.
- Option D: Reduced thermal agitation does not enhance micelle formation; the thermodynamic barrier arises from insufficient solubility, not excess agitation.

Final Answer: Below T_K, surfactant solubility $<$ CMC, so micelle formation ceases $\Rightarrow$ B

Answer: (B) Go Back to Q13

Q14.

Solution

Concept — Role of Binders in Wet Granulation: In wet granulation, a liquid (granulating fluid) activates the binder, which wets primary particles and promotes agglomeration. On drying, the binder forms solid bridges between particles, imparting mechanical strength (cohesiveness and compressibility) to the granules.

Step 1 — Distinguish binder from other excipient roles: Glidants (talc, Aerosil) improve powder flow. Disintegrants (croscarmellose, starch) break the tablet apart. Desiccants prevent moisture uptake. Only binders (PVP, HPMC, gelatin, PEG) create solid bridges that hold granule structure.

Step 2 — Confirm the primary binder function: The primary purpose is inter-particle cohesion via solid-bridge formation on drying, producing granules with adequate compressibility and reduced fines.

Why other options are wrong:

- Option A: Binding particles to form cohesive, compressible granules. **Correct.**

- Option B: Acting as a glidant is the function of colloidal silicon dioxide or talc, not a binder.
- Option C: Promoting disintegration is the function of superdisintegrants such as croscarmellose sodium, not binders.
- Option D: Preventing moisture uptake is the role of desiccants (silica gel) in packaging, not binders.

Final Answer: Binders form solid bridges between particles, producing cohesive granules $\Rightarrow$ A

Answer: (A) Go Back to Q14

Q15.

Solution

Concept — Moisture Content and Hard Gelatin Capsule Properties: Gelatin is a hydrophilic colloid whose mechanical properties are moisture-dependent. Optimal capsule shell moisture (12–15%) imparts flexibility and toughness. At $< 10\%$ moisture, intermolecular hydrogen bonds in the gelatin network are disrupted and the plasticising effect of water is lost, causing the shell to become rigid and brittle.

Step 1 — Understand gelatin's plasticisation by water: Water acts as a plasticiser, increasing chain mobility in the gelatin network. Removing water below the critical threshold eliminates this effect, raising the glass transition temperature and converting the shell from rubbery to glassy state.

Step 2 — Predict physical consequence: A glassy, water-deficient gelatin shell fractures under mechanical stress rather than deforming elastically, causing cracking or splitting during handling, filling, and transport.

Why other options are wrong:

- Option A: Softening/stickiness occurs at *excess* moisture ($> 16\%$), not at deficient moisture.
- Option B: Premature dissolution requires contact with aqueous fluid; low moisture in storage does not cause dissolution.
- Option C: Brittleness and cracking are the direct result of moisture below 10%. **Correct.**
- Option D: The fill material migrating through the shell wall is not related to moisture reduction; this is a compatibility or shell integrity issue unrelated to desiccation.

Final Answer: Moisture $< 10\%$ removes plasticiser (water) $\Rightarrow$ brittle shell that

cracks $\Rightarrow$ C

Answer: (C) Go Back to Q15

Q16.

Solution

Concept — Isotonicity Adjustment Using the NaCl Equivalent (E value): The E value of a substance is the weight of NaCl (in grams) that produces the same osmotic effect as 1 g of that substance. The amount of NaCl contributed by the solute is $E \times C$ (g/100 mL). To render a solution isotonic, the total NaCl equivalent must equal 0.9 g/100 mL.

Step 1 — Calculate NaCl equivalent of 2% w/v glucose: $E_{\text{glucose}} = 0.18$; concentration $= 2$ g/100 mL.
NaCl equivalent $= 0.18 \times 2 = 0.36$ g/100 mL $= 0.36\%$ w/v.

Step 2 — Calculate additional NaCl required: Isotonic NaCl concentration $= 0.9\%$ w/v.
Additional NaCl needed $= 0.90 - 0.36 = 0.54\%$ w/v.

Why other options are wrong:

- Option A: 0.18% is the E value of glucose, not the additional NaCl required.
- Option B: 0.36% is the NaCl equivalent *already contributed* by glucose, not the additional amount.
- Option C: 0.72% would be double the NaCl equivalent of glucose, with no pharmacopoeial basis here.
- Option D: 0.54% is the correct difference needed to reach isotonicity. **Correct.**

Final Answer: Additional NaCl $= 0.90 - (0.18 \times 2) = 0.54\%$ w/v $\Rightarrow$ D

Answer: (D) Go Back to Q16

Q17.

Solution

Concept — Pseudo-First-Order Kinetics in Hydrolysis: A bimolecular reaction $A + B \rightarrow$ products is second-order overall. However, when one reactant (B) is present in vast excess (e.g., the solvent water), its concentration $[B]$ remains essentially constant throughout the reaction. The rate law becomes $r = k_{\text{obs}}[A]$, where $k_{\text{obs}} = k[B]_0$ is the pseudo-first-order rate constant. The reaction appears first-order in the reactant whose concentration is varying.

Step 1 — Apply to aspirin hydrolysis: Aspirin (ester) + $H_2O \rightarrow$ salicylic acid + acetic acid. In dilute aqueous solution, $[H_2O] \approx 55.5$ mol/L, which does not change measurably during the reaction. Thus $k_{\text{obs}} = k[H_2O]$ is effectively constant.

Step 2 — Identify the observed kinetics: Rate $= k_{\text{obs}}[\text{aspirin}]$ — first-order in aspirin, hence pseudo-first-order.

Why other options are wrong:

- Option A: The number of hydrolysable bonds does not determine reaction order; pseudo-first-order arises from the solvent being in excess.
- Option B: Water is in vast excess and remains constant; rate depends only on aspirin concentration. **Correct.**
- Option C: Reaction order is determined by concentration dependence, not by the nature of the transition state per se.
- Option D: The number of products does not determine reaction order.

Final Answer: $[H_2O]$ is constant in dilute solution $\Rightarrow$ rate $\propto$ [aspirin] $\Rightarrow$ pseudo-first-order $\Rightarrow$ B

Answer: (B) Go Back to Q17

Q18.

Solution

Concept — Maillard Reaction in Pharmaceutical Formulations: The Maillard reaction is a non-enzymatic browning reaction between a reducing sugar (aldehydic or ketonic carbonyl group) and a primary or secondary amine. In solid dosage forms, it causes discolouration, loss of drug potency, and formation of potentially toxic condensation products. Lactose is the most commonly used reducing sugar in tablet formulations and is the principal culprit.

Step 1 — Identify the reactive moiety: The reducing sugar end group of lac-

tose (a galactose–glucose disaccharide) provides the free aldehyde/hemiacetal carbonyl that reacts with primary amines ($-NH_2$) via nucleophilic addition to form a Schiff base (N-glycoside), which rearranges through the Amadori rearrangement to produce brown melanoidin pigments.

Step 2 — Select the incompatible excipient: Only reducing sugars (lactose, glucose, maltose) undergo the Maillard reaction. Non-reducing cellulosic excipients, lubricants, and glidants do not carry free aldehyde groups.

Why other options are wrong:

- Option A: Lactose is a reducing disaccharide; its aldehyde group reacts with $-NH_2$ groups in the Maillard reaction. **Correct.**
- Option B: MCC (Avicel) is a non-reducing cellulose; its glucosidic bonds are not reactive with amines under normal conditions.
- Option C: Colloidal silicon dioxide is an inorganic material (SiO_2) with no carbonyl groups; it cannot participate in the Maillard reaction.
- Option D: Magnesium stearate is a fatty acid salt with no reducing sugar functionality; not Maillard-reactive.

Final Answer: Lactose is the reducing sugar that undergoes Maillard condensation with amine drugs $\Rightarrow$ A

Answer: (A) Go Back to Q18

Q19.

Solution

Concept — Zero-Order vs. First-Order Drug Release: Zero-order release means the drug is delivered at a constant rate independent of the remaining drug concentration. On a cumulative release vs. time plot, this appears as a straight line with constant positive slope. First-order release produces a curve that rises steeply initially (when drug content is high) then gradually flattens as the drug is depleted.

Step 1 — Identify the mathematical models: Zero-order: $Q = Q_0 + k_0 t$ (linear; slope $= k_0 =$ constant rate).
First-order: $\ln(1 - f) = -k_1 t$, giving a curved cumulative release profile.

Step 2 — Match to the figure: Formulation P shows a straight diagonal line (constant slope) $\Rightarrow$ zero-order.
Formulation Q shows a steeply rising curve that flattens $\Rightarrow$ first-order.

Why other options are wrong:

- Option A: Formulation Q is first-order (curved), not zero-order.
- Option B: Zero-order requires constant *rate*, not simply eventual complete release; both formulations reach 100% but only P does so linearly.
- Option C: Formulation P increases linearly $\Rightarrow$ constant rate $\Rightarrow$ zero-order. **Correct.**
- Option D: Curved profiles are characteristic of first-order, not zero-order, kinetics.

Final Answer: Straight-line cumulative release (Formulation P) = zero-order kinetics $\Rightarrow$ C

Answer: (C) Go Back to Q19

Q20.

Solution

Concept — Drug Release from Hydrophilic HPMC Matrix Tablets: When an HPMC matrix tablet contacts aqueous media, water diffuses into the matrix, hydrating the polymer. The hydrated HPMC forms a viscous gel layer (hydrogel) around an inner dry core. Drug release from this system proceeds by two simultaneous mechanisms: (1) diffusion of drug through the gel layer, and (2) gradual erosion of the outer gel front as the hydrated polymer dissolves away.

Step 1 — Diffusion mechanism: Drug molecules dissolved within the gel phase diffuse outward through the gel matrix following a concentration gradient (Fickian or anomalous diffusion). The gel layer thickness and tortuosity determine the diffusional resistance.

Step 2 — Erosion mechanism: Simultaneously, the outermost gel layer gradually erodes (dissolves) into the dissolution medium, shortening the diffusion path length and contributing additional drug release. The balance between diffusion and erosion determines the overall release kinetics (Type I to Type II transport).

Why other options are wrong:

- Option A: Osmotic pumping requires a semipermeable membrane and delivery orifice (OROS technology), not present in simple HPMC matrices.
- Option B: Ion exchange is a mechanism used in ion-exchange resin systems; HPMC is a non-ionic polymer.
- Option C: HPMC is not enzymatically degraded under physiological conditions; it is a chemically stable hydroxypropyl methyl ether.
- Option D: Diffusion through the gel layer combined with erosion of the gel front are the established dual mechanisms for HPMC matrices. **Correct.**

Final Answer: HPMC matrix releases drug by gel-layer diffusion AND gel-front erosion $\Rightarrow$ D

Answer: (D) Go Back to Q20

Q21.

Solution

Concept — Fick's First Law and Transdermal Flux: Fick's first law for steady-state membrane permeation is $J = DK\Delta C_m/h$. The flux J is inversely proportional to membrane thickness h. Doubling h while keeping D, K, and ΔC_m constant halves the flux.

Step 1 — Identify the inverse proportionality: $J \propto 1/h$. If $h \to 2h$, then $J \to J/(2) = J/2$.

Step 2 — Verify mathematically: $J_{\text{new}} = DK\Delta C_m/(2h) = \frac{1}{2} \times [DK\Delta C_m/h] = J_{\text{old}}/2$. Flux is halved.

Why other options are wrong:

- Option A: J is halved when h doubles. **Correct.**
- Option B: Doubling would require h to be halved, not doubled.
- Option C: J is not unchanged; the inverse relationship is explicit in Fick's law. Diffusivity D is an intrinsic material property unaffected by thickness.
- Option D: J decreasing to one-quarter would result from h increasing 4-fold, not 2-fold.

Final Answer: $J \propto 1/h$; doubling h gives $J_{\text{new}} = J_{\text{old}}/2 \Rightarrow$ A

Answer: (A) Go Back to Q21

Q22.

Solution

Concept — Thin-Film Hydration (Bangham) Method for Liposomes: The thin-film hydration method, described by Bangham et al. (1965), is the classical technique for liposome preparation. Phospholipids (and cholesterol) are dissolved in a volatile organic solvent (e.g., chloroform, methanol), the solvent is removed under vacuum on a rotary evaporator, a thin dry lipid film is deposited on the flask, and then an aqueous buffer is added and the flask agitated to hydrate the film, producing multilamellar vesicles (MLVs).

Step 1 — Distinguish from other methods: Solvent injection: lipids in ethanol are injected directly into aqueous buffer — no dry film step. REV: lipids dissolved in organic solvent with some aqueous phase (water-in-oil emulsion, then solvent evaporation to form LUVs). Detergent depletion: mixed micelles of lipid + detergent dialysed to remove detergent.

Step 2 — Match the description in the question: The question describes exactly: (i) dissolve in organic solvent, (ii) evaporate to dry film, (iii) hydrate film with buffer $\Rightarrow$ Bangham/thin-film hydration method.

Why other options are wrong:

- Option A: Solvent injection method injects lipid in ethanol into buffer — no dry-film step or rotary evaporator.
- Option B: Thin-film hydration (Bangham) method matches the description exactly. **Correct.**
- Option C: REV involves forming a water-in-oil emulsion before evaporation to produce large unilamellar vesicles (LUVs), not MLVs.
- Option D: Detergent depletion uses dialysis membranes to remove detergent from lipid-detergent mixed micelles; no organic solvent evaporation step.

Final Answer: Organic solvent evaporation $\rightarrow$ dry lipid film $\rightarrow$ aqueous hydration $=$ Bangham method $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept — Aerosol Particle Deposition and MMAD: The site of deposition of inhaled aerosol particles depends critically on their mass median aerodynamic diameter (MMAD). Particles $> 10\,\mu$m deposit in the oropharynx by inertial impaction. Particles 5–10 μm deposit in the conducting airways (bronchi/bronchioles). Particles 1–5 μm reach and deposit in the alveolar region by sedimentation and diffusion. Particles $< 0.5\,\mu$m are largely exhaled without deposition.

Step 1 — Identify the target region: For systemic drug action via pulmonary delivery (e.g., inhaled insulin, prostacyclins), drug must deposit in the alveolar region, which has an enormous surface area ($\sim$140 m^2) and thin epithelium favouring rapid absorption.

Step 2 — Select the optimal MMAD range: MMAD 1–5 μm allows particles to bypass oropharyngeal and bronchial deposition and settle in the deep lung (alveoli)

by gravitational sedimentation.

Why other options are wrong:

- Option A: MMAD 10–20 μm particles deposit in the oropharynx/upper airway by inertial impaction; they never reach alveoli.
- Option B: MMAD 5–10 μm particles deposit mainly in the bronchi and bronchioles, not the alveolar zone.
- Option C: MMAD 1–5 μm is the accepted range for alveolar deposition. **Correct.**
- Option D: MMAD $< 0.5\,\mu$m particles are too small to settle by gravitational forces; they follow tidal airflow and are predominantly exhaled.

Final Answer: MMAD 1–5 μm ensures alveolar deposition for systemic action $\Rightarrow$ C

Answer: (C) Go Back to Q23

Q24.

Solution

Concept — Tablet Friability Test: Friability quantifies the tendency of uncoated tablets to erode or chip during handling, transport, and coating operations. The test is conducted in a rotating drum (friabilator) for exactly 100 revolutions at 25 rpm (4 minutes). The percentage weight loss is calculated from pre- and post-test masses. Both BP and USP specify the same acceptance limit.

Step 1 — Recall the pharmacopoeial limit: $\%\,\text{friability} = \frac{W_{\text{initial}} - W_{\text{final}}}{W_{\text{initial}}} \times 100$. BP (2.9.7) and USP $\langle 1216 \rangle$: the weight loss must generally not exceed **1.0%** of the initial weight after 100 revolutions.

Step 2 — Identify the correct limit: $\leq 1.0\%$ weight loss after 100 revolutions in the friabilator is the standard pharmacopoeial acceptance criterion for routine tablet friability.

Why other options are wrong:

- Option A: $\leq 0.1\%$ is a much stricter limit not specified by BP/USP for routine friability; it may apply to coated tablets or special cases.
- Option B: $\leq 0.5\%$ is not the standard pharmacopoeial limit for routine friability testing.
- Option C: $\leq 2.0\%$ exceeds the accepted limit; tablets failing at $> 1.0\%$ are not suitable for marketing.

- Option D: $\leq 1.0\%$ after 100 revolutions is the correct BP/USP limit. **Correct.**

Final Answer: BP/USP friability limit $=\leq 1.0\%$ weight loss after 100 revolutions $\Rightarrow$ D

Answer: (D) Go Back to Q24

Q25.

Solution

Concept — Glass Container Types for Parenterals: Pharmacopoeial glass containers are classified by their hydrolytic resistance (resistance to leaching of alkali and silica into contained liquids). Type I borosilicate glass contains $\sim$80% SiO_2 and $\sim$12% B_2O_3, providing the highest chemical resistance. It is mandatory for all injectable products that are chemically aggressive (high or low pH) or biologicals (proteins).

Step 1 — Recall pharmacopoeial glass classifications: Type I (borosilicate): highest resistance; mandatory for all aqueous parenterals, especially alkaline solutions and biologicals.
Type II (soda-lime treated): suitable for aqueous solutions with pH $\leq$7 or non-aqueous parenterals.
Type III (soda-lime untreated): for non-parenteral use only.
Type NP: general-purpose glass; not for parenterals.

Step 2 — Apply to the given scenario: A strongly alkaline (pH $>$ 9) protein injectable requires maximum chemical inertness to prevent ion leaching and protein adsorption/degradation at the glass surface $\Rightarrow$ Type I borosilicate glass.

Why other options are wrong:

- Option A: Type I borosilicate provides the highest hydrolytic resistance, essential for alkaline and protein-containing parenterals. **Correct.**
- Option B: Type II treated soda-lime glass is not suitable for pH $>$ 7 aqueous parenterals or proteins; it has lower chemical resistance than Type I.
- Option C: Type III untreated soda-lime glass is explicitly NOT permitted for any parenteral formulation.
- Option D: Type NP glass is designated for non-parenteral (oral, topical) use only.

Final Answer: Strongly alkaline/protein parenterals require Type I borosilicate glass $\Rightarrow$ A

Answer: (A) Go Back to Q25

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	B	3	A	4	D	5	B
6	C	7	A	8	D	9	B	10	A
11	C	12	D	13	B	14	A	15	C
16	D	17	B	18	A	19	C	20	D
21	A	22	B	23	C	24	D	25	A