

Amines, amino acids and condensation polymers in action

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet answers

Every answer shows the formula, the substitution and the result with its unit in bold. Compare your method with the model one, not just the final number, and redo any problem where your steps differ.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.3.11-3.3.13

Problem 1 Classifying four amines

1. $\text{CH}_3\text{CH}_2\text{NH}_2$ is **primary** (one carbon group on N); $(\text{CH}_3)_2\text{NH}$ is **secondary**; $(\text{CH}_3)_3\text{N}$ is **tertiary**; $\text{C}_6\text{H}_5\text{NH}_2$ is **primary** (an aryl group is one carbon group).
2. First bottle: **ethylamine**; last bottle: **phenylamine**.

Problem 2 Why an amine accepts a proton

1. The **lone pair on nitrogen** forms a dative bond with H^+ .
2. $\text{CH}_3\text{NH}_2 + \text{H}^+ \rightarrow \text{CH}_3\text{NH}_3^+$.
3. $\text{CH}_3\text{NH}_2 + \text{HCl} \rightarrow \text{CH}_3\text{NH}_3^+\text{Cl}^-$, the salt is **methyammonium chloride**.

Problem 3 Glycine in a sports drink

1. A is the **ammonium (amine) group**, $-\text{NH}_3^+$; B is the **carboxylate group**, $-\text{COO}^-$.
2. $\text{C}_2\text{H}_5\text{NO}_2$: $2 \times 12.0 + 5 \times 1.0 + 14.0 + 2 \times 16.0 = 24.0 + 5.0 + 14.0 + 32.0 = \mathbf{75.0}$.
3. +1 and -1 cancel, so the overall charge is **zero**.

Problem 4 Addition or condensation

1. **Nylon-6,6** and **PET** are condensation polymers; poly(propene) is an addition polymer.
2. PET forms with loss of **water**.
3. Nylon-6,6 has an **amide** link; PET has an **ester** link.

Problem 5 Reading base pairs

1. X is the A-T pair with **2** hydrogen bonds; Y is the G-C pair with **3** hydrogen bonds.
2. The drawing at Y shows **four** dotted lines instead of three.
3. The complementary strand is **TACGGCAT**. Pairs: A-T, T-A, G-C, C-G, C-G, G-C, T-A, A-T.
A-T pairs = $4 \times 2 = 8$; G-C pairs = $4 \times 3 = 12$; total = **20 hydrogen bonds**.

Problem 6 Ranking four bases

1. Strongest to weakest (smallest pK_b first): **dimethylamine, methylamine, ammonia, phenylamine.**
2. $K_b = 10^{-9.13} = 10^{-9} \times 10^{-0.13} = 0.741 \times 10^{-9} = \mathbf{7.4 \times 10^{-10} \text{ mol/dm}^3}$.
3. The lone pair on nitrogen in phenylamine is partly delocalised into the benzene ring, so it is less available to accept a proton.

Problem 7 pH of a methylamine solution

1. $K_b = [\text{CH}_3\text{NH}_3^+][\text{OH}^-] \div [\text{CH}_3\text{NH}_2]$.
2. $[\text{OH}^-] = \sqrt{(4.6 \times 10^{-4} \times 0.20)} = \sqrt{(9.2 \times 10^{-5})} = \mathbf{9.6 \times 10^{-3} \text{ mol/dm}^3}$.
3. $pOH = -\log(9.6 \times 10^{-3}) = 2.02$; $pH = 14.00 - 2.02 = \mathbf{11.98}$.

Problem 8 Titrating propylamine

1. $n(\text{HCl}) = 0.100 \times 0.0184 = \mathbf{1.84 \times 10^{-3} \text{ mol}}$.
2. The ratio is 1 : 1, so $c = 1.84 \times 10^{-3} \div 0.0250 = \mathbf{0.0736 \text{ mol/dm}^3}$.
3. $0.0736 \times 59.0 = \mathbf{4.34 \text{ g/dm}^3}$.

Problem 9 Making ethylamine from bromoethane

1. $\text{CH}_3\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \mathbf{\text{CH}_3\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}}$ (H: $5 + 6 = 11$ on the left and $5 + 2 + 4 = 11$ on the right; N 2 and Br 1 on both sides).
2. **Nucleophilic substitution**, with NH_3 as the nucleophile.
3. The product amine is also a nucleophile and would attack more bromoethane to give secondary and tertiary amines. A large excess of NH_3 makes it far more likely that bromoethane meets NH_3 , so **mostly the primary amine forms**; the second NH_3 also removes the HBr as NH_4Br .

Problem 10 Forms of alanine

1. Strong acid: $\mathbf{\text{CH}_3\text{CH}(\text{NH}_3^+)\text{COOH}}$, charge +1.
2. Strong alkali: $\mathbf{\text{CH}_3\text{CH}(\text{NH}_2)\text{COO}^-}$, charge -1.
3. The acidic species (+1) moves towards the **cathode** (negative electrode); the alkaline species (-1) moves towards the **anode** (positive electrode).

Problem 11 Two possible dipeptides

1. The $-\text{NH}_2$ of one acid reacts with the $-\text{COOH}$ of the other, giving $-\text{CO}-\text{NH}-$, the **peptide (amide) link**, with loss of water.
2. **Two** dipeptides, Gly-Ala and Ala-Gly, because either amino acid can supply the $-\text{COOH}$ group.
3. $M_r = 75 + 89 - 18 = \mathbf{146}$.

Problem 12 Cutting nylon into monomers

1. The amide link is **-CO-NH-** (the C=O carbon bonded to N).
2. Hydrolysis gives **H₂N(CH₂)₆NH₂** (hexane-1,6-diamine) and **HOOC(CH₂)₄COOH** (hexanedioic acid).
3. With aqueous HCl and heat the amide links hydrolyse and the polymer breaks into **the diacid and the diammonium chloride salt**, because the amine is protonated.

Problem 13 Bottles from ethane-1,2-diol

1. $166 + 62 - 2 \times 18 = 228 - 36 = \mathbf{192}$.
2. $n(\text{repeat units}) = 1000 \div 192 = 5.208 \text{ mol}$; $m(\text{diol}) = 5.208 \times 62 = \mathbf{323 \text{ g}}$.
3. $n(\text{H}_2\text{O}) = 2 \times 5.208 = 10.42 \text{ mol}$; $m = 10.42 \times 18 = \mathbf{188 \text{ g}}$. Check: acid 865 g + diol 323 g – water 188 g = 1000 g.

Problem 14 Breaking down polymers

1. Hydrolysis with NaOH gives **the disodium salt of the diacid and the diol**; acid hydrolysis gives the free diacid and diol.
2. Poly(ethene) has a chain of strong, non-polar C-C and C-H bonds with no ester or amide link for water to attack, so **hydrolysis does not occur**.
3. Monomers can be recovered and reused, and the polymer breaks down in the environment more readily.

Problem 15 Why Kevlar is so strong

1. The link is an **amide** link, and **HCl** is lost.
2. Kevlar has **hydrogen bonds** between the N-H and C=O groups of neighbouring chains, much stronger than the weak London forces between poly(ethene) chains.
3. The benzene rings make the chain **stiff and straight**, so chains line up in sheets and many hydrogen bonds act along the length, which gives high tensile strength.

Problem 16 Identifying an amino acid

1. $\%O = 100 - (40.4 + 7.9 + 15.7) = \mathbf{36.0 \%}$.
2. Moles per 100 g: C 3.37, H 7.9, N 1.12, O 2.25. Dividing by 1.12 gives C 3.0 : H 7.05 : N 1 : O 2.0, so the empirical formula is **C₃H₇NO₂** ($M_r = 89$).
3. The empirical mass is 89, equal to the M_r , so the molecular formula is **C₃H₇NO₂**: **alanine** (2-aminopropanoic acid).

Problem 17 Glycine across the pH range

1. A (pH below 2.34): **+H₃NCH₂COOH** (cation, +1); B: **+H₃NCH₂COO⁻** (zwitterion, 0); C (pH above 9.60): **H₂NCH₂COO⁻** (anion, -1).
2. $pI = (2.34 + 9.60) \div 2 = 11.94 \div 2 = \mathbf{5.97}$.

3. At pH 12, glycine is in region C, so it is an anion and moves towards the **anode**.

Problem 18 Yield of nylon-6,6

1. $n(\text{diamine}) = 8.70 \div 116 = 0.0750 \text{ mol}$, so $n(\text{repeat units}) = 0.0750 \text{ mol}$ and $m = 0.0750 \times 226 = \mathbf{16.95 \text{ g}}$.
2. $\text{Yield} = 14.1 \div 16.95 \times 100 = \mathbf{83.2 \%}$.
3. $n(\text{HCl}) = 2 \times 0.0750 = 0.150 \text{ mol}$; $V = 0.150 \times 24.0 = \mathbf{3.60 \text{ dm}^3}$.

Problem 19 Counting bonds in DNA

1. $A = 30.0 \% \text{ of } 1200 = \mathbf{360}$; $T = A = \mathbf{360}$; $G + C = 1200 - 720 = 480$, so $G = C = \mathbf{240}$.
2. A-T pairs = 360, giving $360 \times 2 = 720$; G-C pairs = 240, giving $240 \times 3 = 720$; total = **1440 hydrogen bonds**.
3. Each G-C pair has three hydrogen bonds against two for A-T, so more energy is needed to separate the strands.

Problem 20 Four amines with one formula

1. Propylamine (primary, $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$); propan-2-amine (primary, $(\text{CH}_3)_2\text{CHNH}_2$); N-methylethanamine (secondary, $\text{CH}_3\text{NHCH}_2\text{CH}_3$); N,N-dimethylmethanamine or trimethylamine (tertiary, $(\text{CH}_3)_3\text{N}$).
2. **Trimethylamine (about 3 °C)**: it has no N-H bond, so its molecules cannot form hydrogen bonds with each other.
3. Propylamine (48 °C) boils higher than propan-2-amine (32 °C). Its straight chain has a larger surface area of contact, so **stronger London forces** act between molecules, while the branched molecule is more compact.