Marks

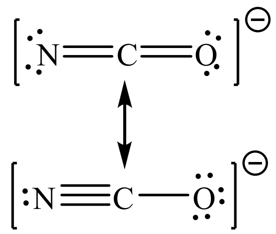
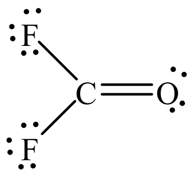
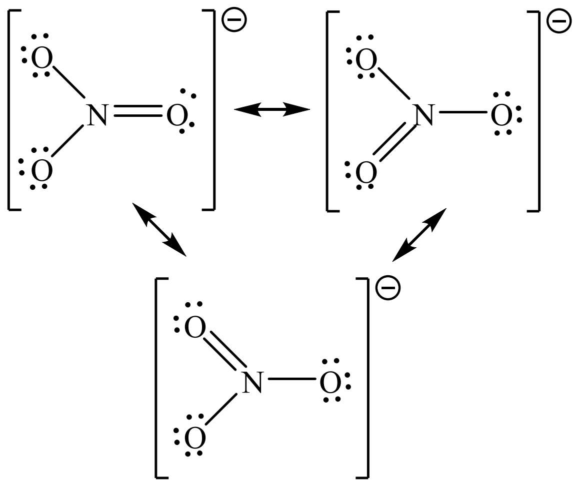
- Give the full electron configuration for the ground state K atom. **2**

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

What are the three quantum numbers that describe the orbital that contains the electron furthest from the nucleus in the K atom?

n = **4**	l = **0**	m_l = **0**

- Draw the Lewis structures, showing all valence electrons for the following species. Indicate which of the species have contributing resonance structures. **4**

NCO^-	COF_2	NO_3^-
		
Resonance: **<u>YES</u>** / NO	Resonance: YES / **<u>NO</u>**	Resonance: **<u>YES</u>** / NO

- Human haemoglobin has a molar weight of 6.45×10^4 g mol^{-1} and contains 3.46 g of iron per kg. Calculate the number of iron atoms in each molecule of haemoglobin. **3**

A mole of haemoglobin has a mass of 6.45×10^4 g = 64.5 kg. As each kilogram contains 3.45 g of iron, a mole contains (64.5 × 3.45) = 223 g of iron.

The atomic mass of iron is 55.85 so this mass of iron corresponds to:

$$\textbf{number of moles of iron} = \frac{\textbf{mass}}{\textbf{atomic mass}} = \frac{\textbf{223}}{\textbf{55.85}} = \textbf{3.98}$$

Answer: **4 iron atoms per molecule**

Marks 3

- If 50 mL of a 0.10 M solution of $AgNO_3$ is mixed with 50 mL of a 0.040 M solution of $BaCl_2$, what mass of AgCl(s) will precipitate from the reaction?

The precipitation reaction, $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$, is a 1:1 reaction of $Ag^+(aq)$ and $Cl^-(aq)$ ions.

Number of moles of Ag^+ = concentration × volume = $0.10 \times \frac{50}{1000} = 0.0050$ mol

As each mole of $BaCl_2(s)$ gives two moles of $Cl^-(aq)$:

Number of moles of Cl^- = $2 \times 0.040 \times \frac{50}{1000} = 0.0040$ mol

$Ag^+(aq)$ is present in excess so $Cl^-(aq)$ is the limiting reagent. Hence, 0.0040 mol of AgCl(s) will be formed.

The molar mass of AgCl(s) = (107.87 (Ag)) + (35.45 (Cl)) = 143.32.

The mass of AgCl(s) formed is:

mass = number of moles × molar mass = 0.0040 × 143.32 = 0.57 g

Answer: **0.57 g**

What is the concentration of NO_3^- ions in the final solution from the reaction above?

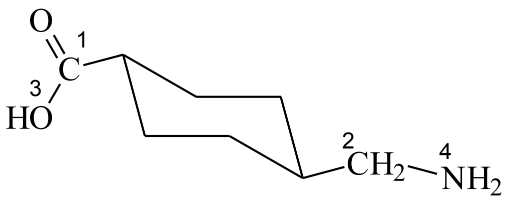
The number of moles of $NO_3^-(aq)$ is 0.0050 mol. After mixing, the final solution has a volume of (50 + 50) = 100 mL. Hence, the concentration is:

$$[NO_3^-] = \frac{\text{number of moles}}{\text{volume}} = \frac{0.0050}{100/1000} = 0.050 \text{ mol}$$

Answer: **0.050 mol**

Marks 4

- Tranexamic acid, *trans*-(4-aminomethyl)cyclohexanecarboxylic acid, is used for the treatment of severe haemorrhage in patients with haemophilia.



Provide the requested information for each of the indicated atoms in tranexamic acid.

Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry/shape of σ-bonding electron pairs around the atom
C-1	**trigonal planar**	**sp^2**	**trigonal planar**
C-2	**tetrahedral**	**sp^3**	**tetrahedral**
O-3	**tetrahedral**	**sp^3**	**bent**
N-4	**tetrahedral**	**sp^3**	**trigonal pyramidals**

3

- Consider the boiling points of the compounds 1-propanol, 1-propanethiol and 1-propaneselenol shown in the table below?

Compound	$CH_3CH_2CH_2OH$	$CH_3CH_2CH_2SH$	$CH_3CH_2CH_2SeH$
Boiling point (° C)	97.2	67.8	147.0

With reference to intermolecular forces, explain briefly why the boiling points increase in the order $CH_3CH_2CH_2SH < CH_3CH_2CH_2OH < CH_3CH_2CH_2SeH$.

Polarisability of atoms increases as the size of the atoms increase. The greater the polarisability, the stronger the dispersion forces. On this basis, the expected boiling point order would be $C_3H_7OH < C_3H_7SH < C_3H_7SeH$.

C_3H_7OH also has hydrogen bonding between the OH groups. H-bonding is a stronger intermolecular force than dispersion forces and this increases the boiling point of C_3H_7OH to be above that of C_3H_7SH. The effect is not enough to push it above the boiling point of C_3H_7SeH.

Marks
5

- Consider the following equation.

$$HBrO(aq) + NH_3(aq) \rightleftharpoons BrO^-(aq) + NH_4^+(aq)$$

Name all of the species in this equation.

HBrO	**hypobromous acid**
BrO^-	**hypobromite ion**
NH_3	**ammonia**
NH_4^+	**ammonium ion**

Complete the following table by giving the correct pK_a or pK_b value where it can be calculated. Mark with a cross (✗) those cells for which insufficient data have been given to calculate a value.

Species	HBrO	NH_3	BrO^-	NH_4^+
pK_a of acid	8.64	✗	✗	**9.24**
pK_b of base	✗	4.76	**5.36**	✗

Determine on which side (left or right hand side) the equilibrium for the reaction above will lie. Provide a brief rationale for your answer.

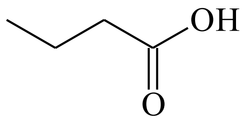
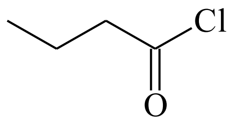
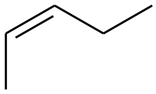
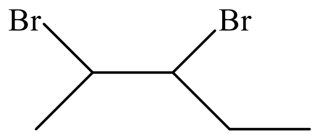
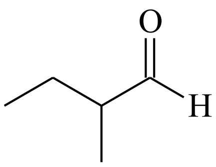
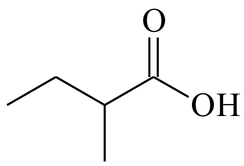
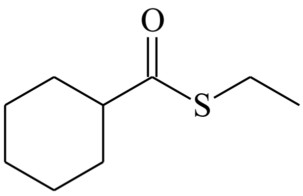
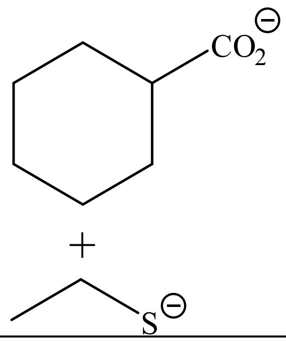
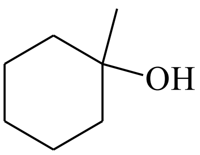
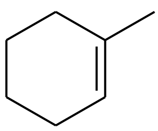
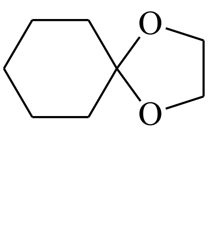
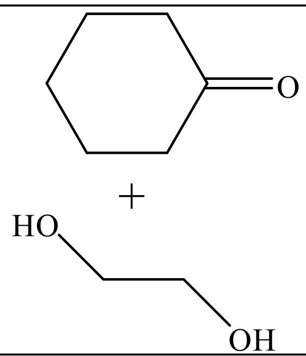
The reaction is the sum of the acid-base equilibra for HBrO and NH_3:

$HBrO(aq) \rightarrow H^+(aq) + BrO^-(aq)$	**$K_a(HBrO) = 10^{-8.64}$**
$H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$	**$K_a(NH_3) = \dfrac{1}{K_a(NH_4^+)} = 10^{+9.24}$**
$HBrO(aq) + NH_3(aq) \rightarrow BrO^-(aq)$	**$K = K_a(HBrO) \times K_a(NH_3)$**

Hence, $K = (10^{-8.64}) \times (10^{+9.24}) = 10^{+0.64} = 4.4$. As $K > 1$, the reaction favours products.

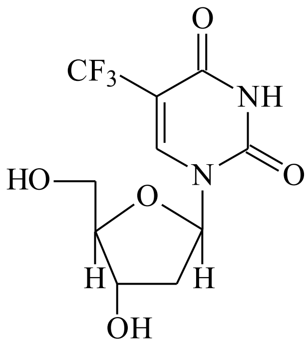
- Complete the following table. Make sure you complete the name of the starting material where indicated.

Marks 11

STARTING MATERIAL NAME (where required)	REAGENTS/ CONDITIONS	CONSTITUTIONAL FORMULA(S) OF MAJOR ORGANIC PRODUCT(S)
 **Name: butanoic acid (or butyric acid)**	**$SOCl_2$**	
 **Name: (Z)-2-pentene**	Br_2 (CCl_4 solvent)	
 **Name: 2-methylbutyraldehyde (or 2-methylbutanal)**	**$Cr_2O_7^{2-}$ / H^+**	
	3 M NaOH / heat	
	**conc. H_2SO_4 / heat**	
	1 M HCl / heat	

Marks
6

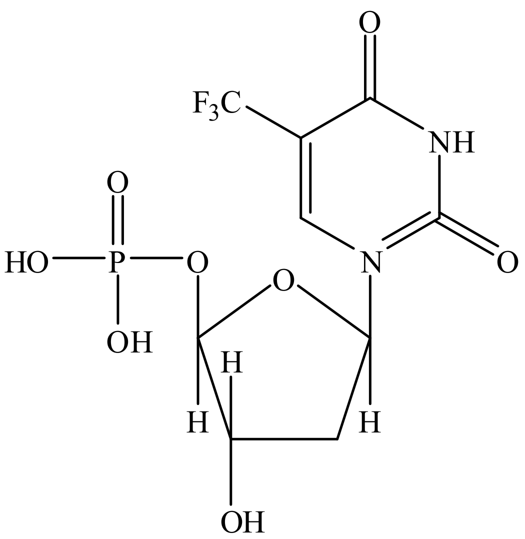
- Trifluridine is an analogue of the nucleoside thymidine and is used clinically as an anti-viral agent. It differs from thymidine in that the methyl group is replaced by a trifluoromethyl group.



trifluridine

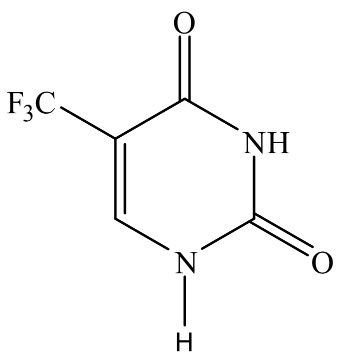
Give the molecular formula of trifluridine.	**$C_{10}H_{11}F_3N_2O_5$**
Classify the sugar present in trifluridine as a furanose or pyranose.	**furanose**
Is the sugar present as the α-anomer or β-anomer?	**β-anomer**

Give an example of a nucleotide derived from trifluridine.

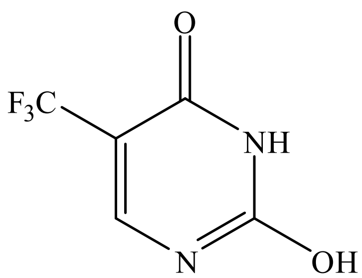


Hydrolysis of trifluridine gives the sugar 2-deoxyribose and a base. Give the structure of the base and the structure of one of its tautomers.

base

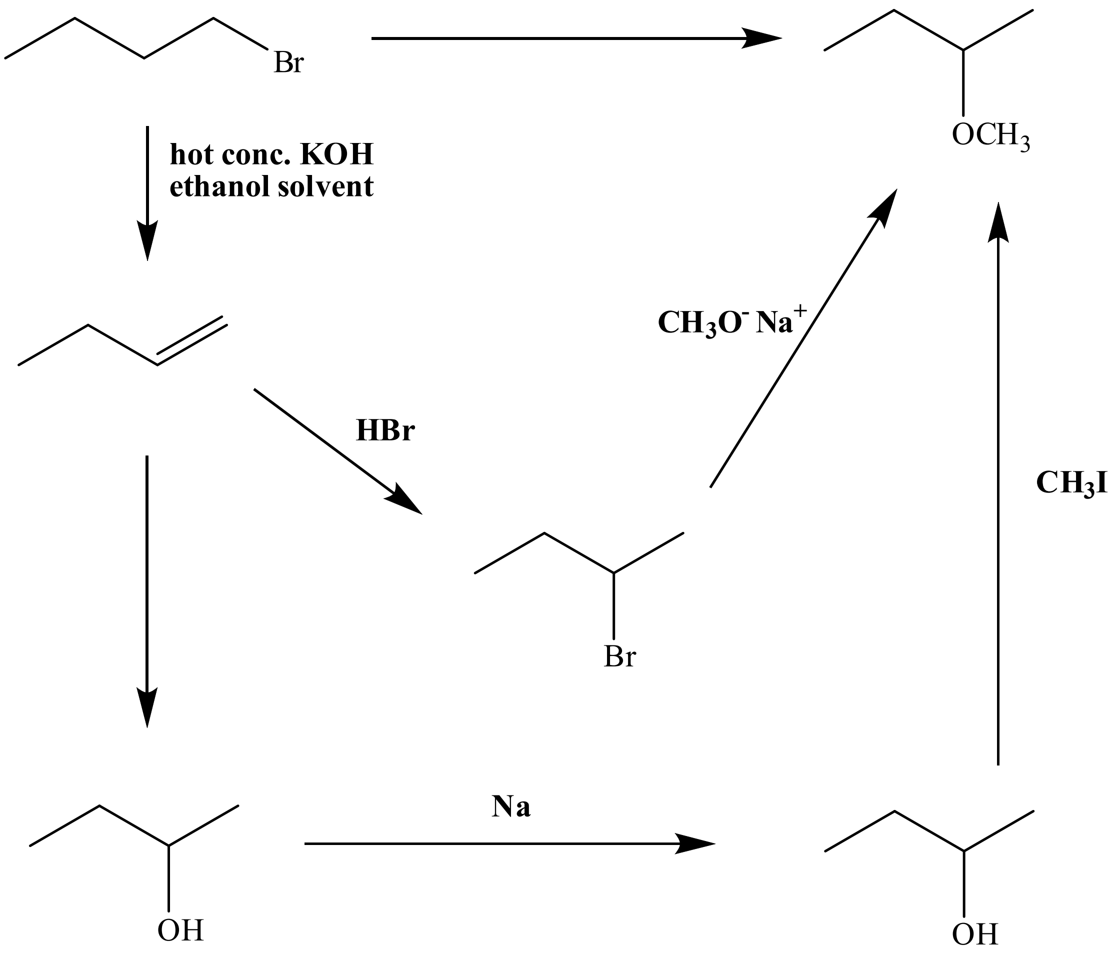


tautomer



4

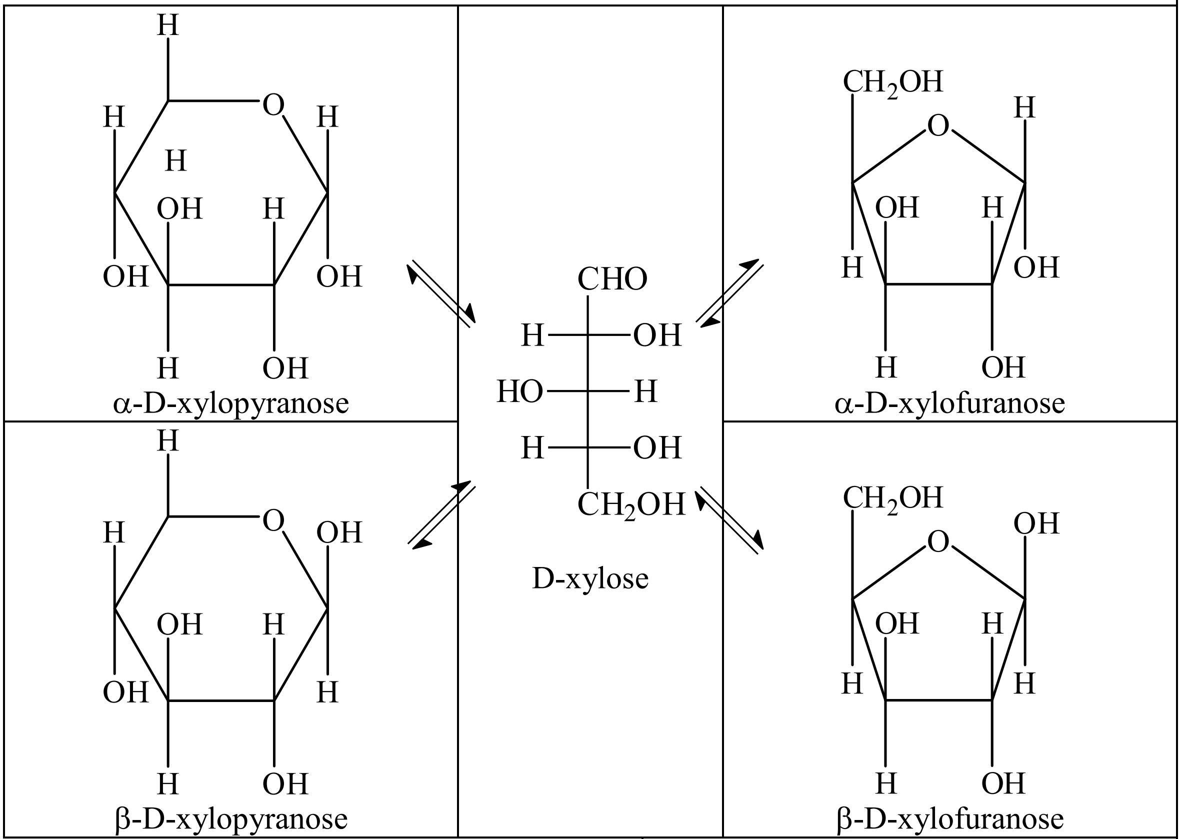
- Show clearly the reagents you would use to carry out the following chemical conversion. Draw constitutional formulas for any intermediate compounds. Note: More than one step is required.



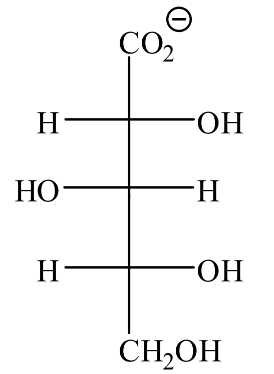
***Two* possible routes are shown.**

Marks
8

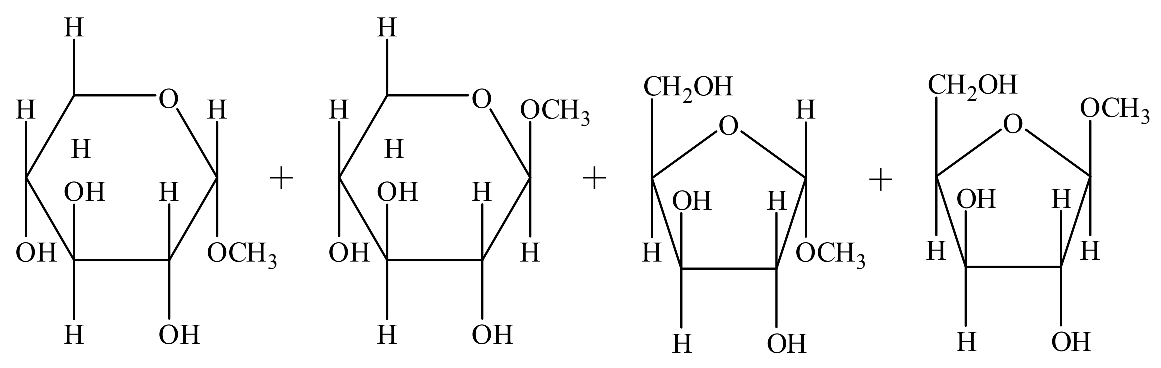
- At equilibrium in aqueous solution, D-xylose exists as a mixture containing the α-pyranose, β-pyranose, α-furanose and β-furanose forms. Draw Haworth formulas in the appropriate boxes below for each of these forms.



Give the formula in Fischer projection, of the product formed when D-xylose is treated with $[Ag(NH_3)_2]^{\oplus}$ / dilute $OH^{\ominus}$.

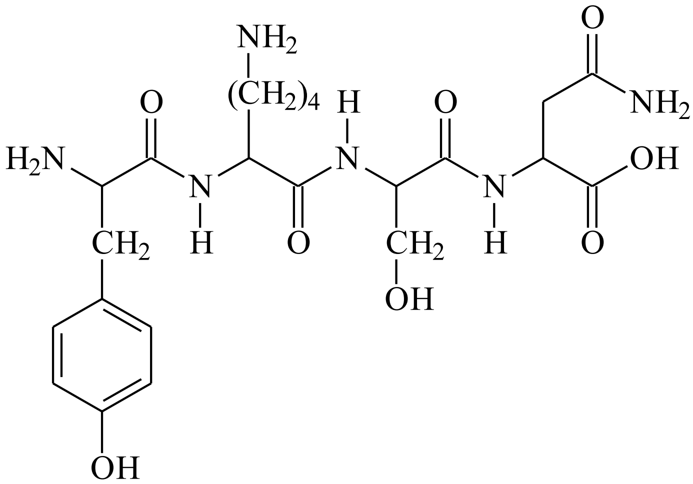


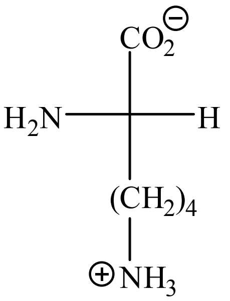
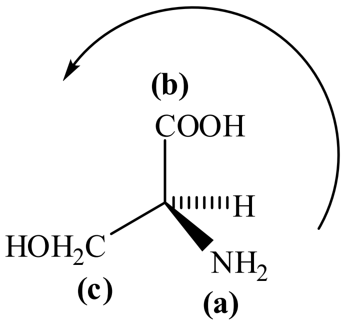
Give the stereoformula of the product(s) formed when β-D-xylopyranose is heated with methanol and an acid catalyst.



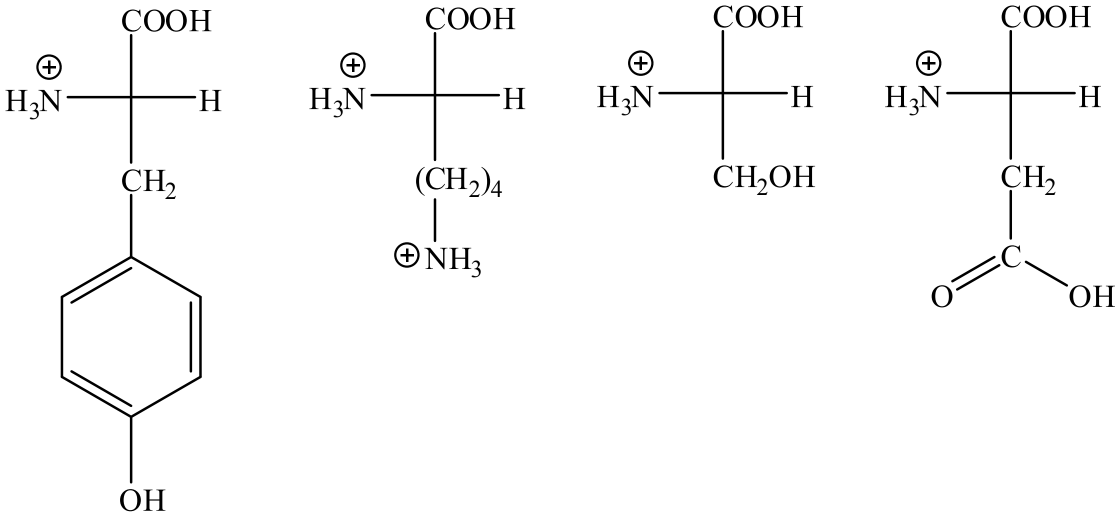
Marks
11

- The constitutional formula of the naturally occurring tetrapeptide, Tyr-Lys-Ser-Asn, is shown below.



Give the Fischer projection of L-Lys as the zwitterion.	Complete the stereoformula of (*S*)-Ser.
	

Give the constitutional formulas in the correct ionic states of the products obtained from the vigorous acidic hydrolysis (6 M HCl) of the tetrapeptide.



Give the constitutional formulas for the following dipeptides present in water at the indicated pH values.

Tyr-Ser at pH 12	Asn-Lys at pH 1