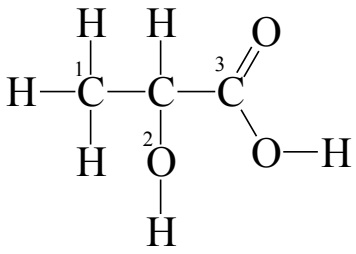
Marks

- The partial Lewis structure of lactic acid, the molecule that forms in muscle during exercise, is shown below. Complete the Lewis structure of lactic acid by drawing the non-bonded electron pairs around the relevant atoms. **7**

2



Complete the following table. **2**

Atom	Geometric arrangement of the groups around the atom	Hybridisation of atom
^{1}C		
^{2}O		
^{3}C		

Name three types of intermolecular interactions expected of lactic acid. **3**

The pK_a of lactic acid is 3.08 and the pK_b of ammonia is 4.76. Determine whether products or reactants are favoured in the following equilibrium reaction. Provide a brief rationale for your answer.

$$CH_3CH(OH)COOH + NH_3 \rightleftharpoons CH_3CH(OH)CO_2^- + NH_4^+$$

Marks 5

- Some micro-organisms thrive under warm, acidic conditions where sulfuric acid is produced as a metabolic by-product from the reaction between sulfur (S), water and oxygen (O_2). Write a balanced equation for this reaction.

Calculate the volume of oxygen that is required to react to completion with 0.0655 g of sulfur at 1.00 atm and 55 °C.

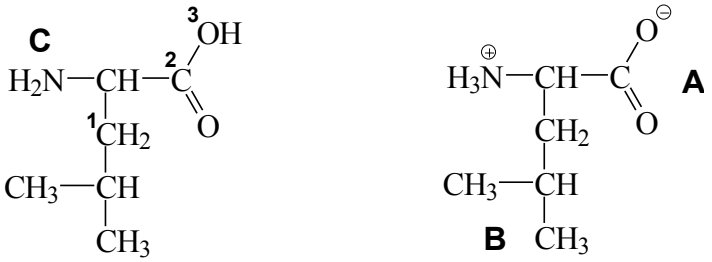
ANSWER:

Calculate the pH of the final solution if the reaction is carried out in 20.0 L of water. Assume that the sulfuric acid fully dissociates.

ANSWER:

Marks 8

- Shown here are the classical and the zwitterionic forms of the amino acid leucine.



List the types of intermolecular interactions in which each of the indicated sites (**A**, **B** and **C**) in leucine could be involved.

A
B
C

Provide the requested information for each of the indicated atoms in leucine.

Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry/shape of σ-bonding electron pairs around the atom
^{1}C			
^{2}C			
^{3}O			

Given that the pK_a of the carboxylic acid group of leucine is 2.32 and the pK_b of the amine group is 4.24, do you expect the classical or the zwitterionic form to predominate when leucine is dissolved in water? In other words, does the following equilibrium lie to the right or left? Show your reasoning.

$$H_2N{-}CH(CH_2CH(CH_3)_2){-}COOH \rightleftharpoons H_3\overset{\oplus}{N}{-}CH(CH_2CH(CH_3)_2){-}\overset{\ominus}{C}O_2$$

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	
BrO^-	
NH_3	
NH_4^+	

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			
pK_b of base		4.76		

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

Marks 5

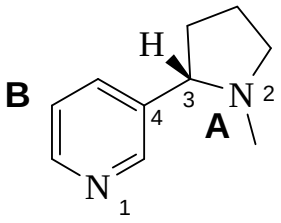
- Glycine, NH_2CH_2COOH, the simplest of all naturally occurring amino acids, has a melting point of 292 °C. The pK_a of the acid group is 2.35 and the pK_a associated with the amino group is 9.78. Draw a structure that indicates the charges on the molecule at the physiological pH of 7.4.

Describe the hybridisation of the two carbon atoms and the nitrogen atom in glycine and the geometry of the atoms surrounding these three atoms.

Glycine has an unusually high melting point for a small molecule. Suggest a reason for this.

Marks 8

- The molecular structure of nicotine, the addictive component of tobacco, is shown below.



List the types of intermolecular interactions that each of the following sites on nicotine would be involved in when it is dissolved in water.

A
B

Provide the requested information for each of the indicated atoms in nicotine.

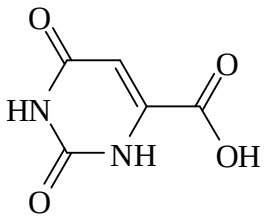
Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry around the atom
N-1			
N-2			
C-3			
C-4			

The pK_b of N-1 is 10.88 and the pK_b of N-2 is 5.98. Draw the structure of the predominant form of nicotine that exists in the human body at pH 7.4.

Marks 4

- Lithium salts, especially lithium carbonate, are commonly used in the treatment of bipolar disorder. Write the net ionic equation for the reaction which occurs between lithium carbonate and hydrochloric acid in the stomach.

Lithium orotate (as a monohydrate salt, $LiC_5H_3N_2O_4 \cdot H_2O$) is a controversial alternative formulation sold in some health food stores. The orotate ion is the conjugate base of orotic acid, whose structure is shown below.

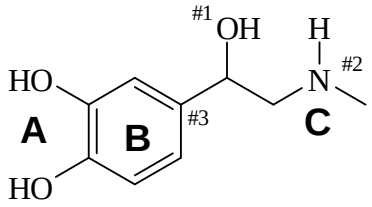


orotic acid

Like the carbonate, lithium orotate is taken orally. Using an equation, comment on any differences between the form in which lithium is bioavailable from these two lithium salts.

Marks 8

- The molecular structure of adrenaline (epinephrine), a hormone involved in the "fight or flight" response, is shown below.



List the types of intermolecular interactions that each of the following sites on adrenaline would be involved in if dissolved in water.

A
B
C

Pharmaceuticals with amine groups are frequently supplied as their "hydrochloride salts". Draw the structure that would result if adrenaline were reacted with one equivalent of HCl. What **additional** intermolecular forces would be present if this form of adrenaline were dissolved in water?

Provide the requested information for each of the indicated sites on adrenaline.

Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry around the atom	Approximate angles around the atom
$^{\#1}$O				
$^{\#2}$N				
$^{\#3}$C				

Marks 7

- Glycine, NH_2CH_2COOH, is the simplest of all naturally occurring amino acids. The pK_a of the acid group is 2.35 and the pK_a associated with the amino group is 9.78. Draw a structure that indicates the charges on the molecule at the physiological pH of 7.4.

Use your structure to illustrate the concept of resonance.

What are the hybridisation states and geometries of the two carbon atoms and the nitrogen atom in glycine?

Propionic acid, CH_3CH_2COOH, has a melting point of –20.7 °C while glycine has a melting point of 292 °C. Suggest a reason why these two molecules have such different melting points.

• Explain the terms '*weak*' and '*strong*' and the terms '*dilute*' and '*concentrated*' in the context of acids and bases.	**Marks 2**