Equilibria

Question Paper 8

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 8

Time Allowed: **62 minutes**

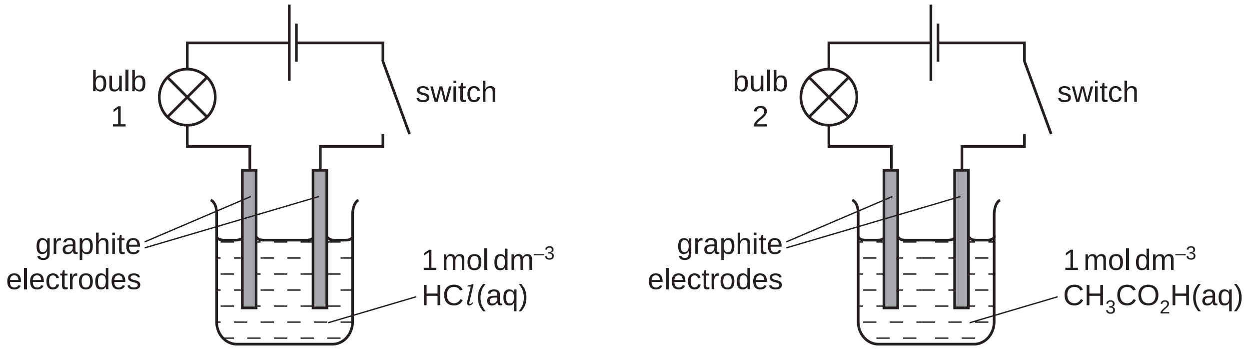
Score: **/51**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** The following circuits were set up using aqueous hydrochloric and aqueous ethanoic acids as electrolytes. Assume that the two circuits were identical apart from the electrolyte.



When the switches were closed, bulb 1 was brighter than bulb 2. Explain why.

....

....

....

.... [2]

(b) State what is meant by a *buffer solution*.

....

....

(ii) Outline how a buffer solution can be prepared from ethanoic acid and a named base.

....

....

[4]

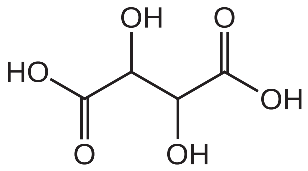
(c) Amino acids such as alanine, $CH_3CH(NH_2)CO_2H$, can act as a buffer solution.
Construct **two** equations to illustrate this.

equation 1

equation 2

[2]

(d) Tartaric acid is present in many plants.



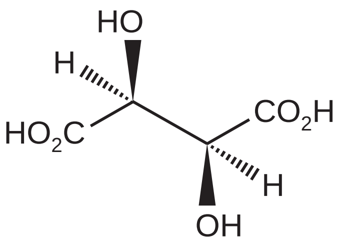
tartaric acid

(i) Tartaric acid has two dissociation constants, K_1 and K_2, for which the pK_a values are 2.99 and 4.40.
Suggest equations showing the two dissociations that give rise to these pK_a values.

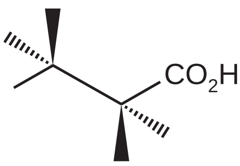
pK_a 2.99

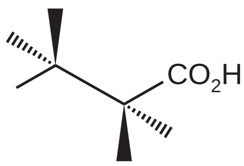
pK_a 4.40

(ii) One stereoisomer of tartaric acid is shown.



Complete the diagrams showing two other stereoisomers of tartaric acid.





[4]

[Total: 12]

2 A sample of a fertiliser was known to contain ammonium sulfate, $(NH_4)_2SO_4$, and sand only.

A 2.96 g sample of the solid fertiliser was heated with 40.0 cm^3 of NaOH(aq), an excess, and all of the ammonia produced was boiled away.

After cooling, the remaining NaOH(aq) was exactly neutralised by 29.5 cm^3 of 2.00 mol dm^{-3} HC*l*.

In a separate experiment, 40.0 cm^3 of the original NaOH(aq) was exactly neutralised by 39.2 cm^3 of the 2.00 mol dm^{-3} HC*l*.

(a) **(i)** Write balanced equations for the following reactions.

NaOH with HC*l*

....

$(NH_4)_2SO_4$ with NaOH

....

(ii) Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of the original NaOH(aq) that was neutralised by 39.2 cm^3 of 2.00 mol dm^{-3} HC*l*.

(iii) Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of NaOH(aq) that remained after boiling the $(NH_4)_2SO_4$.

(iv) Use your answers to **(ii)** and **(iii)** to calculate the amount, in moles, of NaOH that reacted with the $(NH_4)_2SO_4$.

(v) Use your answers to **(i)** and **(iv)** to calculate the amount, in moles, of $(NH_4)_2SO_4$ that reacted with the NaOH.

(vi) Hence calculate the mass of $(NH_4)_2SO_4$ that reacted.

(vii) Use your answer to **(vi)** to calculate the percentage, by mass, of $(NH_4)_2SO_4$ present in the fertiliser.
Write your answer to a suitable number of significant figures.

[9]

(b) The uncontrolled use of nitrogenous fertilisers can cause environmental damage to lakes and streams. This is known as *eutrophication*.

What are the processes that occur when excessive amounts of nitrogenous fertilisers get into lakes and streams?

....

....

.... [2]

(c) Large quantities of ammonia are manufactured by the Haber process.
Not all of this ammonia is used to make fertilisers.
State **one** large-scale use for ammonia, **other than** in the production of nitrogenous fertilisers.

.... [1]

[Total: 12]

3 Ammonium nitrate fertiliser is manufactured from ammonia. The first reaction in the manufacture of the fertiliser is the catalytic oxidation of ammonia to form nitrogen monoxide, NO. This is carried out at about 1×10^3 kPa (10 atmospheres) pressure and a temperature of 700 to 850 °C.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^\ominus = -906\,kJ\,mol^{-1}$$

(a) Write the expression for the equilibrium constant, K_p, stating the units.

K_p =

units .... [2]

(b) What will be the effect on the yield of NO of **each** of the following?
In each case, explain your answer.

(i) increasing the temperature

....

....

....

(ii) decreasing the applied pressure

....

....

....
[4]

(c) The standard enthalpy changes of formation of $NH_3(g)$ and $H_2O(g)$ are as follows.

$NH_3(g)$, $\Delta H_f^\ominus$ = –46.0 kJ mol^{-1} $H_2O(g)$, $\Delta H_f^\ominus$ = –242 kJ mol^{-1}

Use these data and the value of $\Delta H^\ominus_{reaction}$ given below to calculate the standard enthalpy change of formation of NO(g).
Include a sign in your answer.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^\ominus = -906\ \text{kJ mol}^{-1}$$

[4]

[Total: 10]

4 Naturally-occurring α-amino acids, $RCH(NH_2)CO_2H$, can be classified as *amphiprotic* substances. An amphiprotic substance is one which can act as both a Brønsted-Lowry acid and base.

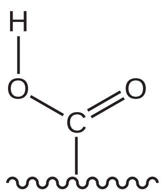
α-amino acid	R group
alanine	CH_3–
aspartic acid	HO_2CCH_2–
glycine	H–
lysine	$H_2N(CH_2)_4$–
threonine	$CH_3CH(OH)$–
serine	$HOCH_2$–

(a) What is the Brønsted-Lowry definition of an acid?

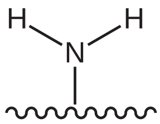
....

.... [1]

(b) All α-amino acids are soluble in water since they can form hydrogen bonds with water molecules and can also exist as zwitterions.
Draw diagrams to show how the carboxylic acid and amino groups of alanine can form hydrogen bonds with water molecules.



carboxylic acid



amino group

(ii) Draw the structure of the zwitterionic form of glycine.

[5]

(c) The amino acid alanine can be formed by the reaction of $CH_3CHClCO_2H$ with an excess of ammonia.
Outline a mechanism for this reaction using curly arrows.

[3]

(d) Amino acids can form different ions at different pH values.
Suggest the structures of the ions formed from the α-amino acids below at the respective pH value.

lysine at pH 1	aspartic acid at pH 14

[2]

(e) How many different **di**peptides is it possible to synthesise, each containing two of the three amino acids alanine, serine and lysine?

....

(ii) Write the structural formula of one of these dipeptides incorporating serine and alanine.

[3]

(f) Most naturally-occurring amino acids have a chiral centre and exhibit stereoisomerism.

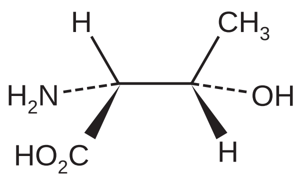
(i) Define the term *stereoisomerism*.

....

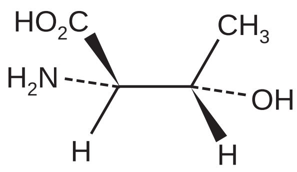
....

There are **four** optical isomers of threonine.

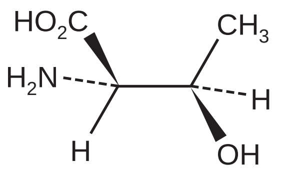
Some of these optical isomers are drawn below.



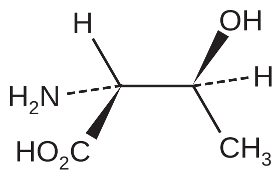
F



G



H



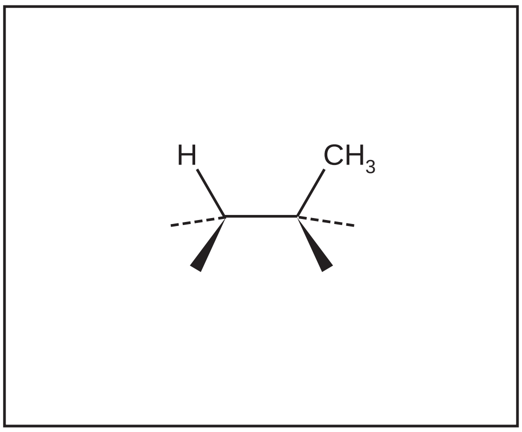
J

When answering this question, remember that completely free rotation about a C–C single bond occurs in these compounds.

(ii) Which of the structures **G**, **H** or **J** is identical to structure **F**? ....

(iii) The other two of the structures **G**, **H** or **J** represent **two** of the **three** other possible optical isomers of threonine.

Complete the following partial structure of the **fourth** optical isomer.



[3]

[Total: 17]