IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

# 8.1 Theories & Reactions of Acids & Bases

8.1.1 Brønsted–Lowry Acids & Bases / 8.1.2 Conjugate Acid-Base Pairs / 8.1.3 Characteristic Reactions of Acids / 8.1.4 Neutralization / 8.1.5 Acid-base Titrations / 8.1.6 pH & [$H^+$] / 8.1.7 Interpreting pH / 8.1.8 The Ionic Product of Water / 8.1.9 Acid-Base Calculations / 8.1.10 pH Meters & Universal Indicator / 8.1.11 Strong & Weak Acids & Bases / 8.1.12 Comparing Strong & Weak Acids / 8.1.13 Acid...

| | |
|---|---|
| Easy (4 questions) | /24 |
| Medium (5 questions) | /33 |
| Hard (4 questions) | /33 |
| **Total Marks** | **/90** |

**Scan here to return to the course**
or visit savemyexams.com

# Easy Questions

**1 (a)** Define a *Brønsted–Lowry acid*.

.....

**(1 mark)**

**(b)** Which species in the following reaction acts as a Brønsted-Lowry base.

$$HSO_4^-(aq) + H_3O^+(aq) \rightleftharpoons H_2SO_4(aq) + H_2O(l)]$$

.....

**(1 mark)**

**(c)** Which species in the following equation is acting as a Brønsted-Lowry acid.

$$CO_3^{2-}(aq) + H^+(aq) \rightleftharpoons HCO_3^-(aq)$$

.....

**(1 mark)**

**(d)** Explain, using the Brønsted-Lowry theory, how water can act either as an acid or a base.

.....

.....

**(2 marks)**

**2 (a)** Describe the difference between an amphiprotic and amphoteric species.

.....

**(1 mark)**

**(b)** Write an equation to show ammonia, $NH_3$, acting as both a Brønsted–Lowry base and a Brønsted–Lowry acid.

Brønsted–Lowry base: .....

Brønsted–Lowry acid: .....

.....

.....

**(2 marks)**

**(c)** The equations for two acid-base reactions are given below.

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$$
$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$$

Identify two different amphiprotic species in the above reactions.

.....

**(1 mark)**

**(d)** i) State what is meant by the term conjugate base.

[1]

ii) State the conjugate base of the hydroxide ion, $OH^-$

[1]

.....

.....

**(2 marks)**

**3 (a)** State an equation for the reaction of magnesium carbonate with dilute hydrochloric acid.

.....

**(1 mark)**

**(b)** State an equation for the reaction of lithium oxide with dilute nitric acid.

.....

**(1 mark)**

**(c)** Which acid and base would be required to produce ammonium sulfate, $(NH_4)_2SO_4$

.....

.....

**(2 marks)**

**(d)** Nitric acid and calcium hydroxide react together.

i) State the type of reaction that takes place.

[1]

ii) State the formula of the products of the reaction.

[1]

iii) State the sign of the enthalpy change for this reaction.

[1]

.....

.....

.....

**(3 marks)**

**4 (a)** Identify one conjugate acid-base pair in the reaction.

$$OCl^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + HOCl(aq)$$

.....

**(1 mark)**

**(b)** State an equation for the reaction of aluminium hydroxide with dilute sulfuric acid.

.....

**(1 mark)**

**(c)** State an equation for the reaction of calcium hydrogencarbonate with dilute phosphoric acid, $H_3PO_4$.

.....

**(1 mark)**

**(d)** Write the formulae for the following:

i) Carbonic acid. [1]

ii) Ammonium sulfate. [1]

iii) Magnesium ethanoate. [1]

.....

.....

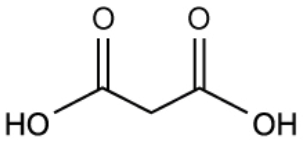
.....

**(3 marks)**

# Medium Questions

**1 (a)** Malonic acid is a naturally occurring acid found in fruits and vegetables and is shown in **Figure 1.**

**Figure 1**




The first dissociation of malonic acid is:

$$C_3H_4O_4\,(aq) + H_2O\,(l) \rightleftharpoons C_3H_3O_4^-\,(aq) + H_3O^+\,(aq)$$

Identify one conjugate acid-base pair from the equation.

.....

**(1 mark)**

**(b)** The equilibrium constant for the first dissociation of malonic acid is $1.48 \times 10^{-3}$.

State, with a reason, the strength of malonic acid.

.....

.....

.....

**(3 marks)**

**(c)** The anion $C_3H_3O_4^-$ may be classified as *amphiprotic*. Explain the meaning of *amphiprotic* and write equations, using $C_3H_3O_4^-$, to illustrate your answer.

.....

**(1 mark)**

**(d)** Under the right conditions, malonic acid can react with ethanol to form diethyl malonate, a diester.

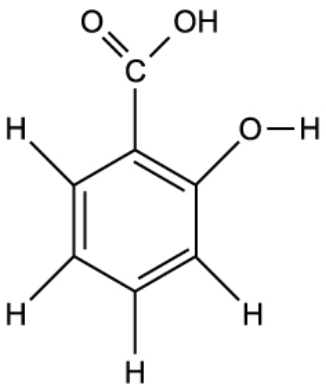
Draw a displayed formula for diethyl malonate showing all the bonds.

.....

**(1 mark)**

**2 (a)** Salicylic acid has the structure shown below in **Figure 1**.

**Figure 1**




Draw the structure of the conjugate base of salicylic acid, showing **all** the atoms and **all** the bonds.

.....

**(1 mark)**

**(b)** Predict what would be seen if a small amount of copper (II) oxide was added to an aqueous solution of salicylic acid, $HOC_6H_4COOH$, and warmed.

Write a balanced equation for the reaction.

.....

.....

**(2 marks)**

**(c)** Suggest, with a reason, whether salicylic acid is likely to be soluble in water.

.....

**(1 mark)**

**(d)** Determine the relative molecular mass, $M_r$, of salicylic acid using Table 6 from the Data book.

.....

**(1 mark)**

**3 (a)** Write balanced equations to show the separate reactions between ethanoic acid and calcium carbonate, $CaCO_3$, magnesium oxide, MgO, and aluminium hydroxide, $Al(OH)_3$.

**(3 marks)**

**(b)** In **Table 1** below, suggest the names and formulae of the acids and bases needed to make the specified salts.

**Table 1**

| Acid | Base | Salt |
|---|---|---|
| | | Copper nitrate, $Cu(NO_3)_2$ |
| | | Calcium phosphate, $Ca_3(PO_4)_2$ |

**(2 marks)**

**(c)** The ethanoate ion, $CH_3COO^-$, carbon dioxide, $CO_2$, and the ethoxide ion, $CH_3CH_2O^-$, all contain carbon oxygen bonds.

Deduce the order in carbon to oxygen bond length from shortest to longest and explain your answer.

**(3 marks)**

**(d)** Ethanoic acid, $CH_3COOH$, shows two absorptions in an infrared spectrum that are not present in the spectrum of ethanol.

Using Table 26 of the Data book, state the wavenumber range of these absorptions and the bonds that cause them.

.....

.....

**(2 marks)**

**4 (a)** Glycolic acid, $C_2H_4O_3$, is a colourless, odourless crystalline solid that is highly soluble in water and behaves as a Brønsted–Lowry acid.

i) Define the term Brønsted–Lowry acid.

ii) State one difference between Brønsted–Lowry acids and the traditional theory of acids as substances that dissociate in water to form hydrogen ions.

.....

.....

**(2 marks)**

**(b)** The systematic IUPAC name for glycolic acid is 2-hydoxyethanoic acid.

Draw the structural formula for its conjugate base, showing **all** the atoms and bonds.

.....

**(1 mark)**

**(c)** Write an equation for the reaction between glycolic acid, $C_2H_4O_3$, and limescale, $CaCO_3$. State and explain one observation you would make.

.....

.....

**(2 marks)**

**(d)** State one reason why you would use glycolic acid to remove the limescale in a kettle at home, but not hydrochloric acid.

.....

**(1 mark)**

**5 (a)** An alkaline solution is formed when sodium hydrogencarbonate is dissolved in water.

Write an equation for the reaction and explain why the solution is alkaline.

.....

.....

**(2 marks)**

**(b)** State whether the $HCO_3^-$ ion is behaving as a Brønsted–Lowry acid or as a base and give a reason for your answer.

.....

.....

**(2 marks)**

**(c)** Carbon dioxide gas dissolves in rainwater to form carbonic acid. State the formula of the conjugate base of carbonic acid.

.....

**(1 mark)**

**(d)** Carbonic acid and sulfuric acid can be described as *diprotic* acids. Explain the meaning of *diprotic.*

.....

**(1 mark)**

# Hard Questions

**1 (a)** Explain why an ammonium ion can not behave as a Brønsted-Lowry base.

.....

.....

**(2 marks)**

**(b)** State and explain the acid-base character of aqueous ammonia at 298 K.

.....

.....

**(2 marks)**

**(c)** Acids can be classed as monoprotic, diprotic and triprotic. Sulfuric acid is a diprotic acid.

i) State the equation for the first ionisation step of sulfuric acid, including state symbols.

ii) Label the conjugate acid and base pairs in your answer to part i).

.....

.....

**(2 marks)**

**(d)** The second ionisation step is for the ionisation of sulfuric acid is as follows.

$$HSO_4^-\ (aq) + H_2O\ (aq) \rightleftharpoons SO_4^{2-}\ (aq) + H_3O^+\ (aq)$$

Suggest why the second ionisation step reaches equilibrium.

.....

**(1 mark)**

**2 (a)** Sodium hydrogen carbonate solution, $NaHCO_3$ (aq) , can act as an amphiprotic species. State the equation for the reaction fo $NaHCO_3$ (aq) with the following compounds:

i) Sodium hydroxide solution.

[1]

ii) Hydrochloric acid.

[1]

.....

.....

**(2 marks)**

**(b)** Using your answer to part a) i) and ii), explain why $NaHCO_3$ is amphiprotic.

.....

.....

.....

**(3 marks)**

**(c)** Phosphine is usually prepared by heating white phosphorus, one of the allotropes of phosphorus, with concentrated aqueous sodium hydroxide.

The equation for the reaction is.

$$P_4\,(s) + 3OH^-\,(aq) + 3H_2O\,(l) \rightarrow PH_3\,(g) + 3H_2PO_2^-\,(aq)$$

Identify the amphiprotic species in this reaction giving the formulas of both species it is converted to when it behaves in this manner.

.....

.....

.....

**(3 marks)**

**(d)** 1.68 g of white phosphorus was used to make phosphine

i) Calculate the amount, in mol, of white phosphorus used.

[1]

ii) This phosphorus was reacted with 50.0 $cm^3$ of 3.00 mol $dm^{-3}$ aqueous sodium hydroxide. Deduce, showing your working, which was the limiting reagent.

[1]

iii) Determine the excess amount, in mol, of the other reagent.

[1]

iv) Using section 2 of the data booklet. Determine the volume of phosphine, measured in $cm^3$ at standard temperature and pressure, that was produced.

[1]

.....

.....

.....

.....

**(4 marks)**

**3 (a)** Oxalic acid, $H_2C_2O_4$, is a weak diprotic acid and can be used in titrations. State the equation for the reaction of oxalic acid with sodium hydroxide.

.....

.....

**(2 marks)**

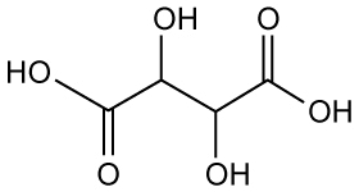
**(b)** The ionisation of oxalic acid occurs in two steps. State equations for both of these steps.

.....

.....

**(2 marks)**

**(c)** Tartaric acid shown below behaves as a Brønsted-Lowry acid when it reacts with calcium hydroxide, $Ca(OH)_2$. Sketch the structure of the salt formed from this reaction.




.....

.....

.....

**(3 marks)**

**4 (a)** Using ionic equations state how $HPO_4^{2-}$ can behave as an amphiprotic and amphoteric species.

.....

.....

.....

.....

**(4 marks)**

**(b)** Gallium oxide behaves as an amphoteric oxide. State two equations to show how gallium oxide reacts with a strong monoprotic acid and strong base.

Reaction with strong monoprotic acid

.....

Reaction with strong base

.....

.....

.....

**(2 marks)**

**(c)** Identify the Brønsted-Lowry acids in the following reaction.

$$CH_3CH_2O^-(aq) + H_2O(l) \rightleftharpoons CH_3CH_2OH(aq) + OH^-(aq)$$

.....

**(1 mark)**