

# Acid/Base terminology

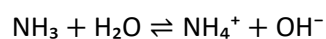
1. Which species is the **conjugate base** of  $\text{H}_2\text{CO}_3$ ?

- A.  $\text{CO}_3^{2-}$
- ☒ B.  $\text{HCO}_3^-$
- C.  $\text{H}_3\text{O}^+$
- D.  $\text{OH}^-$
- E.  $\text{H}_3\text{CO}_4$

*The conjugate base is formed when **one proton is removed**.*



2. In the reaction



Which is a conjugate acid–base pair?

- ☒ A.  $\text{NH}_3 / \text{NH}_4^+$
- B.  $\text{NH}_3 / \text{OH}^-$
- C.  $\text{H}_2\text{O} / \text{OH}^-$
- D.  $\text{NH}_4^+ / \text{OH}^-$
- E.  $\text{H}_2\text{O} / \text{NH}_4^+$

*Conjugate pairs differ by **one proton only**.*



3. Which base is **strongest** in water?

- A.  $\text{NO}_3^-$
- B.  $\text{Cl}^-$
- ☒ C.  $\text{CH}_3\text{COO}^-$
- D.  $\text{SO}_4^{2-}$

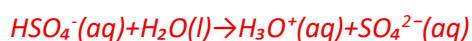
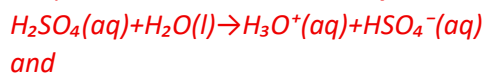
*$\text{CH}_3\text{COO}^-$  is the conjugate base of a **weak acid (acetic acid)**.*

*The conjugate bases of **strong acids** ( $\text{NO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ) are **very weak bases**.*

4. Which acid is **diprotic**?

- A.  $\text{HNO}_3$
- B.  $\text{HCl}$
- C.  $\text{CH}_3\text{COOH}$
- D.  $\text{H}_3\text{PO}_4$
- E.  $\text{H}_2\text{SO}_4$

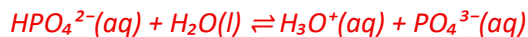
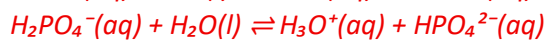
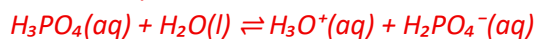
*A diprotic acid can donate **two protons**.*



5. Which species can donate **three protons** in aqueous solution?

- A.  $\text{CH}_3\text{COOH}$
- B.  $\text{H}_3\text{PO}_4$
- C.  $\text{CH}_3\text{CH}_2\text{COOH}$
- D.  $\text{NH}_4^+$
- E.  $\text{NH}_3$

*$\text{H}_3\text{PO}_4$  is triprotic*



6. Which reaction represents the **second ionisation** of sulfuric acid?

- A.  $\text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{SO}_4^{2-}$
- B.  $\text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{HSO}_4^-$
- C.  $\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$
- D.  $\text{SO}_4^{2-} \rightarrow \text{H}^+ + \text{SO}_4^{3-}$
- E.  $\text{HSO}_4^- \rightarrow \text{H}^+ + \text{SO}_4^{2-}$

*Diprotic acids ionise stepwise.*

*Second step removes  $\text{H}^+$  from  $\text{HSO}_4^-$ .*

7. Which species is **amphiprotic**?

- A.  $\text{CO}_3^{2-}$
- B.  $\text{H}_3\text{O}^+$
- C.  $\text{NO}_3^-$
- D.  $\text{Na}^+$
- E.  $\text{HCO}_3^-$

*Amphiprotic substances can donate or accept a proton.*

*$\text{HCO}_3^-$  can become  $\text{H}_2\text{CO}_3$  or  $\text{CO}_3^{2-}$ .*

8. Which statement is **correct**?

- A. All amphoteric substances are amphiprotic
- B. Amphoteric substances react only with acids
- ☒ C. Amphiprotic substances donate and accept protons
- D. Amphoteric means only proton transfer
- E. Amphiprotic substances react only with bases

*Amphiprotic specifically refers to proton transfer.*

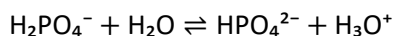
*Amphoteric is broader (can react as acid or base, not always via protons).*

9. Which statement is correct?

- ☒ A. Strong acids have weak conjugate bases
- B. Weak acids have weak conjugate bases
- C. Strong acids have strong conjugate bases
- D. Acid strength does not affect conjugate strength
- E. Conjugate acids and bases have equal strength

*There is an inverse relationship between acid and conjugate base strength.*

10. In the reaction



$\text{H}_2\text{PO}_4^-$  is acting as a:

- A. Base only
- ☒ B. Acid only
- C. Spectator ion
- D. Salt
- E. Both an acid and a base

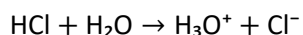
*$\text{H}_2\text{PO}_4^-$  donates a proton  $\rightarrow$  acts as an acid.*

## Short-answer questions

1. Define the term **conjugate acid–base pair**.

*A conjugate acid/base pair consists of two species that differ by one proton, formed when an acid donates a proton or a base accepts a proton.*

2. Identify the conjugate acid and conjugate base in the reaction:



- Conjugate acid:  $\text{H}_3\text{O}^+$
- Conjugate base:  $\text{Cl}^-$

3. Explain why  $\text{CH}_3\text{COO}^-$  is a stronger base than  $\text{NO}_3^-$ .

*$\text{CH}_3\text{COO}^-$  is the conjugate base of a weak acid, whereas  $\text{NO}_3^-$  is the conjugate base of a strong acid.*

*Therefore, acetate has a greater tendency to accept a proton.*

4. A student described the species  $\text{HCO}_3^-$  as amphoteric. Is the student correct? Explain your answer.

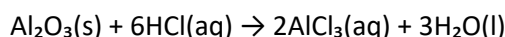
*Yes, the student is correct.*

*The hydrogen carbonate ion,  $\text{HCO}_3^-$ , is amphoteric because it can act as both an acid and a base.*

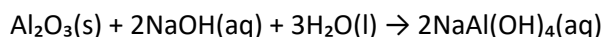
- As an acid,  $\text{HCO}_3^-$  donates a proton:  
$$\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{CO}_3^{2-} + \text{H}_3\text{O}^+$$
- As a base,  $\text{HCO}_3^-$  accepts a proton:  
$$\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-$$

*Because  $\text{HCO}_3^-$  can both donate and accept a proton, it is amphoteric (and more specifically, amphiprotic).*

5.  $\text{Al}_2\text{O}_3$  undergoes two reactions as shown below.



and



- i. Compare and contrast an amphoteric substance and an amphiprotic substance.

*An amphoteric substance is one that can react as either an acid or a base, depending on the substance it reacts with. This does not require proton transfer and may involve oxide or hydroxide ions.*

*An amphiprotic substance is a species that can both donate and accept a proton ( $\text{H}^+$ ) in acid–base reactions.*

*Similarity -Both amphoteric and amphiprotic substances can behave as either an acid or a base.*

*Difference- Amphiprotic behaviour specifically involves proton transfer, whereas amphoteric behaviour is broader and does not necessarily involve protons.*

ii. Using aluminium oxide as an example classify this substance as an amphoteric or amphiprotic substance. Explain why.

*Using aluminium oxide as an example, classify this substance as amphoteric or amphiprotic. Explain why.*

*Answer:*

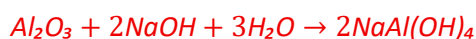
*Aluminium oxide is classified as amphoteric, not amphiprotic.*

*Explanation:*

*Al<sub>2</sub>O<sub>3</sub> reacts with acids, such as HCl, where it behaves as a base:*



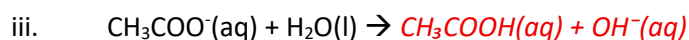
*It also reacts with bases, such as NaOH, where it behaves as an acid:*



*However, aluminium oxide does not donate or accept protons directly, so it is not amphiprotic*

6. Consider the following species,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$  and  $\text{CH}_3\text{COO}^-$ .

a. Write the balanced equation for the reaction of each base with water.



b. Which reaction produces the most amount of  $\text{OH}^-$ ? Explain why.

*The reaction of  $\text{CH}_3\text{COO}^-$  with water produces the most  $\text{OH}^-$ .*

- The conjugate base of a weak acid ( $\text{CH}_3\text{COOH}$ ) is stronger and more likely to accept a proton from water.*
- $\text{SO}_4^{2-}$  and  $\text{NO}_3^-$  are conjugate bases of strong acids ( $\text{H}_2\text{SO}_4$  and  $\text{HNO}_3$ ), so they react very little with water.*