

Chapter 7 — Acid Base Chemistry

2. Questions for Short Answers

1. Choose Arrhenius acids among the following compounds: HF, NH_4^+ , H_2SO_3 , SO_3 , H_2S , H_2O

Ans: According to Arrhenius an acid is a substance which dissociates in water to give a proton (H^+) or a hydroxonium ion (H_3O^+). On this basis the Arrhenius acids in the list are HF, H_2SO_3 and H_2S , because all three contain ionizable hydrogen and release H^+ in water. NH_4^+ is not an Arrhenius acid (though it is a Bronsted-Lowry acid), SO_3 is a non-metal oxide which is not itself an acid but becomes one only after reacting with water to form H_2SO_4 , and H_2O ionizes to such a very small extent that it is not classed as an Arrhenius acid.

2. How does calcium metal react with dilute H_2SO_4 ?

Ans: Calcium is a reactive metal, so like magnesium and zinc it displaces hydrogen from a dilute acid. It reacts with dilute sulphuric acid to form the salt calcium sulphate and hydrogen gas is evolved: $\text{Ca(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{CaSO}_4(\text{aq}) + \text{H}_2(\text{g})$. The escaping hydrogen can be identified by bringing a burning match stick near the mouth of the test tube, where it burns with a pop sound.

3. Which salt is formed when HCl reacts with BaCO_3 ?

Ans: Acids decompose metal carbonates, evolving carbon dioxide gas and forming a salt and water. Barium carbonate therefore reacts with hydrochloric acid to give barium chloride as the salt: $\text{BaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{BaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$. So the salt formed is barium chloride, BaCl_2 .

4. How will you justify that HSO_4^- is a Bronsted-Lowry acid?

Ans: A Bronsted-Lowry acid is a substance that donates a proton. Sulphuric acid is a diprotic acid and ionizes in two steps; in the second step the hydrogen sulphate ion itself donates its remaining proton to a water molecule: $\text{HSO}_4^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$. Since HSO_4^- gives up a proton to water in this reaction, it is acting as a proton donor and is therefore a Bronsted-Lowry acid; SO_4^{2-} is its conjugate base.

5. Why is HCl not edible although it is present in the stomach and responsible for digestion of food?

Ans: The hydrochloric acid present in the stomach is produced by the cells in the lining of the stomach in a strictly controlled amount, and it is very dilute; the stomach wall is also protected by a lining of mucus so the acid does not damage it. Laboratory hydrochloric acid, on the other hand, is a mineral acid and mineral acids are generally very strong acids which ionize completely in water. Taken by mouth it would be far more concentrated than the stomach acid and would burn the mouth, throat and food pipe, which have no such protective lining. This is also why even a small excess of acid produced in the stomach itself causes acidity and a burning sensation, which has to be neutralized with antacids such as calcium hydroxide and magnesium hydroxide.

3. Constructed Response Questions

1. What chemical name will you give to soap as a compound?

Ans: Soap is prepared from stearic acid, so chemically it is the sodium salt of a long-chain fatty acid — sodium stearate. When stearic acid, which is an organic acid, is neutralized by an alkali such as sodium hydroxide, the reaction is an ordinary acid-base neutralization which gives a salt and water, and that salt is the soap. A soap made with potassium hydroxide instead of sodium hydroxide is potassium stearate, which is a soft soap.

2. In the presence of a drop of an acid, water is known to ionize as: $\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$. In your opinion, which name will be suitable for water: an acid, a base or both?

Ans: Both. Water is an amphoteric compound, which means a compound that can behave as an acid as well as a base. The equation shows water giving a proton, H^+ , so here it is behaving as an acid; at the same time it gives OH^- , and it can also accept a proton from another acid. In the reaction $\text{HCl}(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$ water accepts a proton and so acts as a base, while in $\text{NH}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$ water donates a proton and so acts as an acid. Which role water plays depends on the other compound with which it reacts.

3. Why does Na_2CO_3 behave like a base in water?

Ans: Sodium carbonate does not contain any hydroxyl group, so by the Arrhenius definition it should not be a base at all — this is one of the limitations of the Arrhenius concept. In water, however, the carbonate ion is ionized by water: it accepts a proton from a water molecule and leaves behind a hydroxide ion, $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$. The solution therefore contains OH^- ions and turns red litmus blue, so sodium carbonate behaves like a base. According to Bronsted-Lowry it is clearly a base because the carbonate ion is a proton acceptor.

4. Is NaHCO_3 a base or an acid? Justify your answer.

Ans: Sodium bicarbonate behaves as a base. Acids decompose hydrogen carbonates, evolving carbon dioxide gas and forming a salt and water — for example $2\text{NaHCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{CO}_2(\text{g})$. This is exactly the behaviour of a base towards an acid, and it is the reason sodium bicarbonate solution followed by vinegar is used to clear a blocked drain. In Bronsted-Lowry terms the HCO_3^- ion accepts a proton from the acid, so it is a proton acceptor and therefore a base. (Strictly speaking HCO_3^- can also donate its own proton, so it is amphoteric, but in ordinary reactions with acids it acts as a base.)

5. What is the difference between a strong acid and a concentrated acid?

Ans: The two words describe two entirely different things. Strength is a property of the acid itself and depends upon the extent to which it is ionized in water: a strong acid ionizes completely in water and gives a large amount of hydroxonium ions, as hydrochloric acid does, while a weak acid ionizes only to a very limited extent — glacial acetic acid has a percent ionization of only 0.132%. Concentration, on the other hand, is a property of the solution and tells us how much acid is dissolved in a given amount of water. So, a solution can be a concentrated weak acid, such as concentrated acetic acid, or a dilute strong acid, such as the very dilute hydrochloric acid present in the stomach. A strong acid does not have to be concentrated, and a concentrated acid does not have to be strong.