Aqueous Solutions & Acidity

Acids:	**Bases**:
Taste sour	Taste bitter
pH less than 7	pH greater than 7
Conduct electricity	Conduct electricity
Corrosive (cause chemical burns)	Caustic (cause chemical burns)
Turns litmus red	Turns litmus blue
Slippery, soapy feel	

Metal oxides are basic.

$K_2O \rightarrow 2K^+ + O^{2-}$

$O^{2-} + H_2O \rightarrow 2OH^-$

Non-metal oxides are acidic.

$SO_2 + H_2O$ [double arrow] H_2SO_4

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

H_3PO_4 [double arrow] $H_2PO_4^- + H^+$

$H_2PO_4^- \rightarrow HPO_4^{2-} + H^+$

$HPO_4^{2-} \rightarrow PO_4^{3-} + H^+$

Q: 632mL of 291ppm copper(II) sulfate solution is mixed with 1mL of 1.00mol L^{-1} sodium sulfide solution.

[a] Write balanced equation and net ionic equation.

$CuSO_{4\,(aq)} + Na_2S_{(aq)} \rightarrow CuS_{(s)} + Na_2SO_{4\,(aq)}$

$Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow CuS_{(s)}$

[b] Write observations.

A blue solution is combined with a colourless solution, forming a black precipitate.

[c] What mass of precipitate forms?

m($CuSO_4$) = 0.184g

n($CuSO_4$) = $\frac{0.184}{M(CuSO_4)}$ = 0.00115mol

m(NaS) = 0.001 x 1 = 0.001

NaS is the limiting reagent as it produces less CuS.

m(CuS) = 0.001 x M(CuS) = 0.0956g

Q: 531g of manganese dissolves in excess phosphoric acid.

[a] Write ionic equation.

$3Mn_{(s)} + 2H_3PO_{4\,(aq)} \rightarrow Mg_3(PO_4)_{2\,(s)} + 3H_{2\,(g)}$

[b] Write observations.

A silver solid dissolves in a colourless solution, forming a white precipitate and bubbles of colourless odourless gas.

[c] What volume of gas is produced?

n(Mn) = $\frac{531}{54.94}$ = 9.67mol

mol ratio = 3.22mol

n(H_2) = 3 x 3.22 = 9.67mol

$V(H_2) = 9.67 \times 22.71 = 219L$

Q: How many calcium ions are needed to precipitate all the phosphate ions from a 365mL volume of 3.2mol L^{-1} sodium phosphate solution?

$2Na_3PO_{4\,(aq)} + 3Ca^{2+}_{(aq)} \rightarrow Ca_3PO_{4\,(s)} + 6Na^{+}_{(aq)}$

$3Ca^{2+}_{(aq)} + 2PO_4^{2-}{}_{(aq)} \rightarrow Ca_3(PO_4)_{2\,(s)}$

$n(Na_3PO_4) = 0.365 \times 3.2 = 1.17mol$

mol ratio = $\frac{1.17}{2}$ = 0.584mol

$n(Ca^{2+}) = 3 \times 0.584 = 1.75mol$

$\#Ca^{2+} = 1.75 \times 6.022 \times 10^{23} = 1.1 \times 10^{24}$

Q: 124mL of 67ppm barium hydroxide is mixed with excess magnesium sulfate. What mass of precipitate forms?

$Ba(OH)_{2\,(aq)} + MgSO_{4\,(aq)} \rightarrow BaSO_{4\,(s)} + Mg(OH)_{2\,(s)}$

$m(Ba(OH)_2) = 0.00831g$

$n(Ba(OH)_2) = \frac{0.00831}{M(Ba(OH)_2)} = 4.85 \times 10^{-5}$ mol

$n(BaSO_4) = n(Ba(OH)_2) = 4.85 \times 10^{-5}$ mol

$m(BaSO_4) = 0.0113g$

$n(Mg(OH)_2) = n(Ba(OH)_2) = 4.85 \times 10^{-5}$ mol

$m(Mg(OH)_2) = 0.00283g$

m(precipitate) = 0.0113 + 0.00283 = 0.014g

Q: How many ions are there in 3.99L of 2.71 mol L^{-1} tin(IV) phosphate solution, assuming it's soluble?

$Sn_3(PO_4)_{4\,(aq)} \rightarrow$ 10.8mol

$n(Sn^{4+}) = 3 \times 10.8 = 32.4mol$

$\#Sn^{4+} = 32.4 \times 6.022 \times 10^{23} = 1.95 \times 10^{25}$

$n(PO_4^{3-}) = 43.3mol$

$\#PO_4^{3-} = 43.3 \times 6.022 \times 10^{23} = 2.60 \times 10^{25}$

Q: Write balanced ionic equations and observations for the following equations:

[a] Hydrochloric acid + sodium hydroxide.

$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

2 colourless solutions are combined with no observable change.

[b] Ammonium nitrate solid + sodium hydroxide solution.

$NH_4NO_{3\,(s)} + OH^-_{(aq)} \rightarrow NH_{3\,(g)} + H_2O_{(l)}$

White solid dissolves in colourless solution, releasing bubbles of colourless, pungent gas.

[c] Copper (II) sulfate solution + sodium sulfide solution.

$Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow CuS_{(s)}$

Blue solution and colourless solution are mixed, creating a black precipitate.

[d] Copper (II) carbonate solid + acetic acid solution.

$CuCO_{3\,(s)} + 2CH_3COOH_{(aq)} \rightarrow Cu^{2+}_{(aq)} + Co_{2\,(g)} + H_2O_{(l)} + 2CH_3COO^-_{(aq)}$

Green solid dissolves in colourless solution, creating a blue solution and bubbles of colourless, odourless gas.

[e] Chromium + nitric acid.

$2Cr_{(s)} + 6H^{+}_{(aq)} \rightarrow 2Cr^{3+}_{(aq)} + 3H_{2(g)}$

Silver solid dissolves in colourless solution, creating a deep green solution and bubbles of colourless, odourless gas.

[f] Carbon dioxide + barium hydroxide solution.

$CO_{2(g)} + Ba^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow BaCO_{3(s)} + H_2O_{(l)}$

Colourless, odourless gas is bubbled through a colourless solution, forming a white precipitate.

Q: Write balanced equations (ionic where appropriate) and observations for each of the following:

[a] Ammonium nitrate solution + potassium hydroxide solution.

$NH_4^{+}{}_{(aq)} + OH^{-} \rightarrow NH_{3(g)} + H_2O_{(l)}$

2 colourless solutions are mixed, creating bubbles of colourless pungent gas.

[b] Copper (II) sulfate solution + sodium sulfide solution.

$Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow CuS_{(s)}$

A blue solution is mixed with a colourless solution, creating a black precipitate.

[c] Phosphoric acid + calcium carbonate.

$2H_3PO_{4\,(aq)} + 3CaCO_{3\,(s)} \rightarrow 3CO_{2\,(g)} + Ca3(PO4)_{2\,(s)} + 2PO_4^{-} + 3H_2O_{(l)}$

A white solid dissolves in a colourless solution, creating bubbles of a colourless, odourless gas and a white precipitate.

[d] Hydrofluoric acid + calcium.

$Ca_{(s)} + 2HF_{(aq)} \rightarrow H_{2\,(g)} + 2F^{-}_{(aq)} + Ca^{2+}_{(aq)}$

A silver solid dissolves in a colourless solution, creating bubbles of a colourless, odourless gas.

Q: Devise a test to distinguish each of the following pairs of substances. Write observations for each.

[a] Copper carbonate$_{(s)}$ + copper (II) chloride $_{(s)}$.

Add both to water. One green solid will not dissolve. This is the copper (II) carbonate and the other will dissolve creating a blue solution, this is the copper (II) chloride.

[b] Sodium nitrate $_{(aq)}$ + sodium iodide $_{(aq)}$.

Combine both with silver nitrate solution, one colourless solution will mix with the other colourless solution, resulting in no observable change. This is the $NaNO_3$. The other will form a pale yellow precipitate, this is the sodium iodide.

Q: Explain how to create a supersaturated solution of sodium acetate.

1. Heat the water.
1. Dissolve $NaCH_3COO$ in the water until no more will dissolve.
2. Remove any excess solid $NaCH_3COO$.
3. Gently cool the solution.

Q: Determine concentration of silver ions in solution after 1505mL of 3.24 mol L^{-1} silver nitrate is mixed with 1499mL of 0.545 mol L^{-1} copper(II) chloride solution.

$2AgNO_{3\,(aq)} + CuCl_{2\,(aq)} \rightarrow 2AgCl_{\,(s)} + CuCl_{2\,(aq)}$

$n(AgNO_3) = 3.24 \times 1.501 = 4.86$ mol

$n(CuCl_2) = 0.545 \times 1.499 = 0.817$ mol

$n(AgNO_3 \text{ used}) = 2 \times n(CuCl_2) = 2 \times 0.817 = 1.63$

$n(AgNO_3 \text{ left}) = n(AgNO_3) - n(AgNO_3 \text{ used}) = 4.86 - 1.63 = 3.23$ mol

$n(Ag^+) = n(AgNO_3 \text{ left}) = 3.23$ mol

$c = \frac{3.23}{1.501+1.499} = 1.08$ mol L^{-1}

Q: What volume of ammonia is produced when 632mL of 343ppm ammonium nitrate reacts with excess sodium hydroxide solution.

$343 = \frac{m(NH_4 \in mg)}{0.632}$

$m(NH_4NO_3) = 343 \times 0.632$

$m(NH_4NO_3) = \frac{0.217}{M(NH_4NO_3)} = 0.00271$g

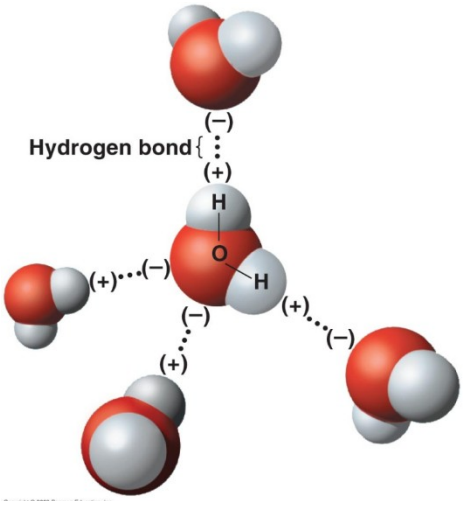
$NH_4NO_{3\,(aq)} + NaOH_{\,(aq)} \rightarrow NH_{3\,(g)} + H_2O_{\,(l)} + NaNO_{3\,(aq)}$

$n(NH_3) = n(NH_4NO_3) = 0.0027$ mol

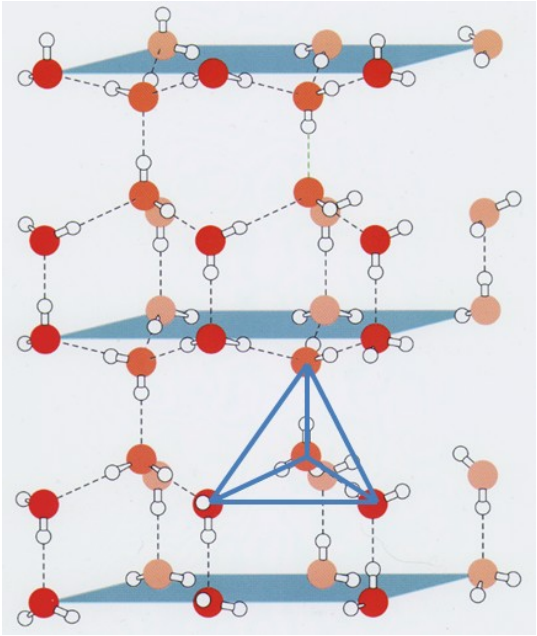
$V(NH_3) = 22.71 \times n(NH_3) = 0.00615L = 61.5mL$

Unique properties of water:

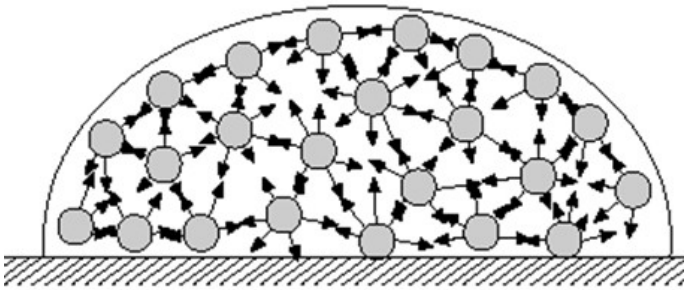
- High melting and boiling points (0 °C and 100 °C respectively) – due to strong hydrogen bonds present between molecules (water molecules can form up to four hydrogen bonds per molecule).



- Density – at 4 °C water has a density around 1.0 g mL^{-1} and can go as low as 0.934 g mL^{-1} at −180 °C. In solid water, molecules arrange themselves in a tetrahedral arrangement such that the water molecules are further apart in ice than in water.

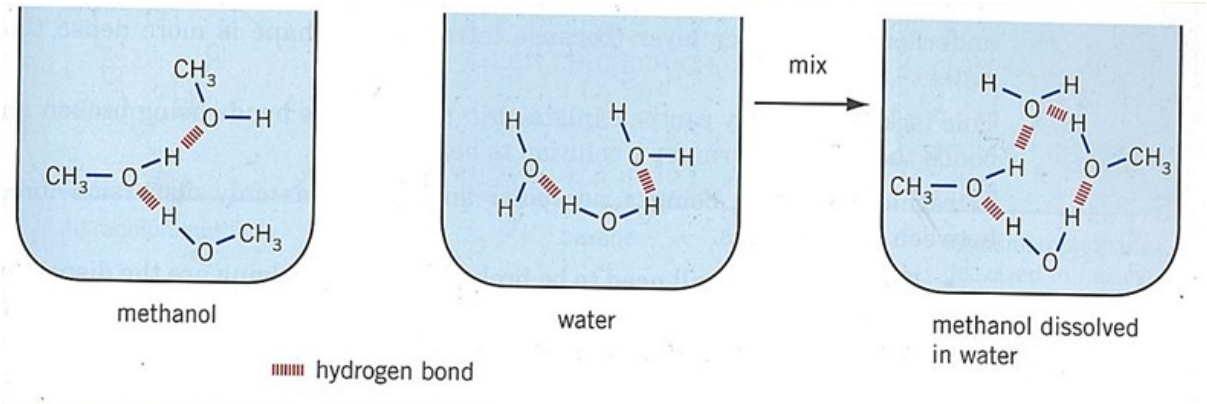


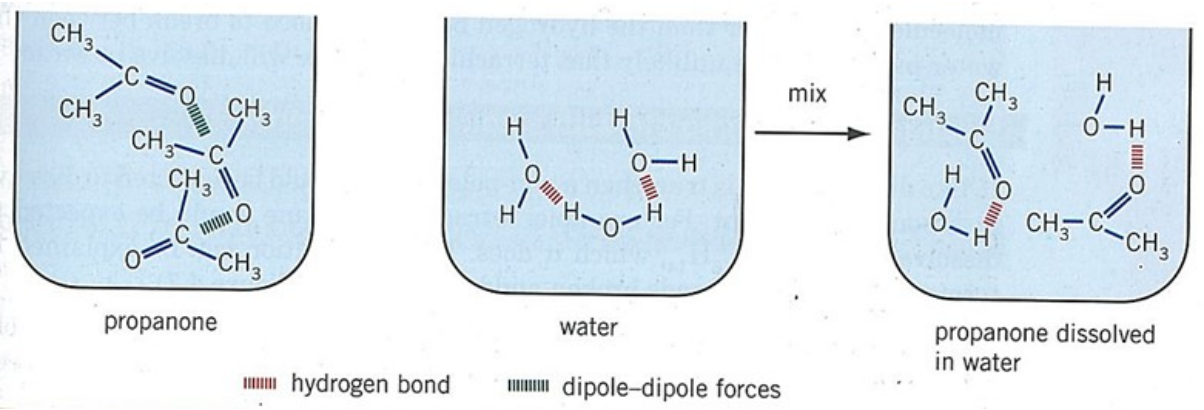
- High surface tension – A liquid's tendency to reduce its surface area. Due to the strong intermolecular forces at the surface of the liquid being unbalanced, causing the molecules to be pulled inwards.



Water is often referred to as the universal solvent because of the large range of substances (solutes) that are soluble in water. The solubility of (and reasons for) various substances in water are:

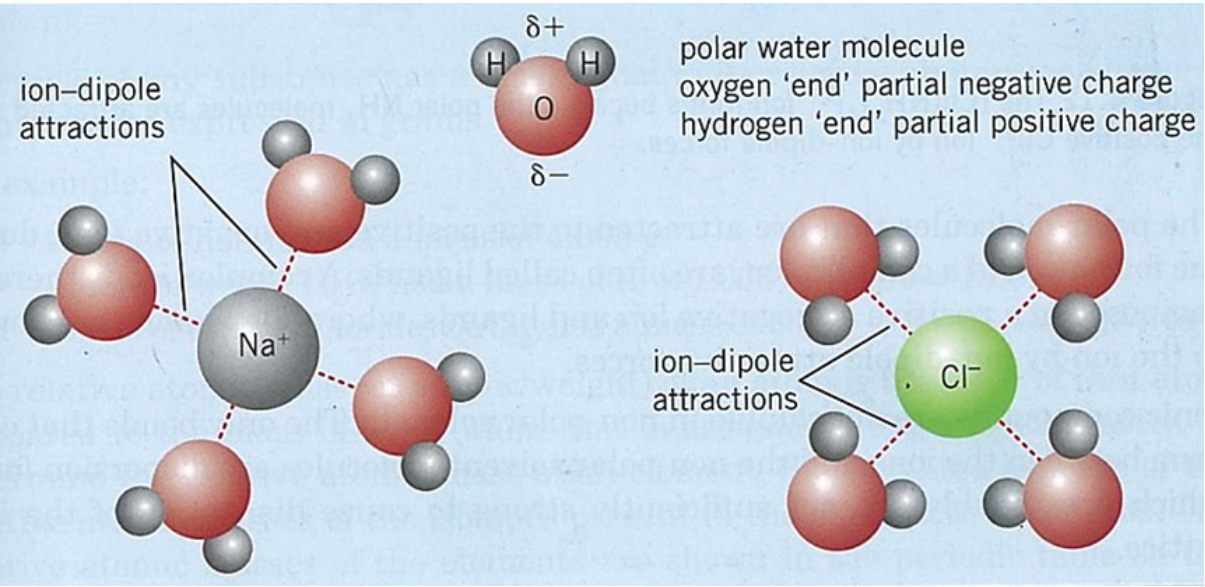
- Polar substances –solubility in water may be due to favourable hydrogen bonding interactions between the water and polar substance (e.g. methanol in water) or dipole-dipole interactions between the water and polar substance (e.g. hydrogen sulfide in water).
- In order for a solute to be soluble in a solvent, the strength of the interactions between the solute and solvent molecules must be strong enough to overcome the solvent-solvent interactions and the solute-solute interactions (i.e. the energy produced from the formation of the solvent-solute interactions must be greater than the energy required to overcome the solute-solute and solvent-solvent interactions).





Not all polar substances are soluble in water - dispersion forces can become more and more significant which can then interfere with the favourable intermolecular forces set up between the solute and solvent.

Ionic substances – many are soluble in water due to electrostatic forces of attraction set up between the ions and water molecules called ion-dipole forces. In this type of force positive ions are attracted to the negative end of the water dipole and negative ions are attracted to the positive end of the water dipole.



Making supersaturated solution:

- Make saturated solution at high temperature by dissolving solute in solvent.
- Very slowly cool the solution, lowering the solubility below the concentration.

Q: 2.7L of phosphoric acid is exactly neutralised b y 1.9L of 2.5mol/L sodium hydroxide solution. What's the concentration of the phosphoric acid in ppm?

$H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$

n(NaOH) = cV = 2.5 x 1.9 = 4.75mol

$n(H_3PO_4) = \frac{1}{3}n(NaOH) = 1.58mol$ * *Important step*

$m(H_3PO_4) = nM = 1.58 \times (1.008 \times 3 + 30.07 + 16 \times 4) = 155.2g$

= 155157mg

$c(H_3PO_4) = \frac{155157}{2.7} = 5500ppm = 57000ppm$ (2SF)

Q: 3.7L of sulfuric acid reacts with calcium carbonate producing 132L of CO_2. What's the concentration of acid in mol/L?

$n(CO_2) = \frac{132}{22.71} = 5.81mol$

$n(H_2SO_4) = n(CO_2) = 5.81mol$ * *Important step*

$c(H_2SO_4) = \frac{n}{V} = \frac{5.81}{3.7} = 1.6mol/L$