Topic 18: Acids and bases

10 hours

Essential idea: The acid–base concept can be extended to reactions that do not involve proton transfer.

18.1 Lewis acids and bases

Nature of science:

Theories can be supported, falsified or replaced by new theories—acid–base theories can be extended to a wider field of applications by considering lone pairs of electrons. Lewis theory doesn't falsify Brønsted–Lowry but extends it. (2.5)

Understandings:

- A Lewis acid is a lone pair acceptor and a Lewis base is a lone pair donor.
- When a Lewis base reacts with a Lewis acid a coordinate bond is formed.
- A nucleophile is a Lewis base and an electrophile is a Lewis acid.

Applications and skills:

- Application of Lewis' acid–base theory to inorganic and organic chemistry to identify the role of the reacting species.

Guidance:

- Both organic and inorganic examples should be studied.
- Relations between Brønsted–Lowry and Lewis acids and bases should be discussed.

International-mindedness:

- Acid–base theory has developed from the ideas of people from different parts of the world through both collaboration and competition.

Theory of knowledge:

- The same phenomenon can sometimes be explored from different perspectives, and explained by different theories. For example, do we judge competing theories by their universality, simplicity or elegance?

Utilization:

Syllabus and cross-curricular links:
Topics 4.2 and 4.3—covalent molecules and Lewis dot diagrams
Topic 13.2—transition metal complexes
Topic 20.1—nucleophiles

Aims:

- **Aim 6**: Transition metal complexes could be experimentally explored.
- **Aim 7**: Animations can be used to distinguish between the different acid–base theories.

Essential idea: The equilibrium law can be applied to acid–base reactions. Numerical problems can be simplified by making assumptions about the relative concentrations of the species involved. The use of logarithms is also significant here.

18.2 Calculations involving acids and bases

Nature of science:

Obtaining evidence for scientific theories—application of the equilibrium law allows strengths of acids and bases to be determined and related to their molecular structure. (1.9)

Understandings:

- The expression for the dissociation constant of a weak acid (K_a) and a weak base (K_b).
- For a conjugate acid base pair, $K_a \times K_b = K_w$.
- The relationship between K_a and pK_a is (pK_a = -log K_a), and between K_b and pK_b is (pK_b = -log K_b).

Applications and skills:

- Solution of problems involving [H^+ (aq)], [OH^-(aq)], pH, pOH, K_a, pK_a, K_b and pK_b.
- Discussion of the relative strengths of acids and bases using values of K_a, pK_a, K_b and pK_b.

Guidance:

- The value K_w depends on the temperature.
- The calculation of pH in buffer solutions will only be assessed in options B.7 and D.4.
- Only examples involving the transfer of one proton will be assessed.
- Calculations of pH at temperatures other than 298 K can be assessed.
- Students should state when approximations are used in equilibrium calculations.
- The use of quadratic equations will not be assessed.

International-mindedness:

- Mathematics is a universal language. The mathematical nature of this topic helps chemists speaking different native languages to communicate more objectively.

Utilization:

Syllabus and cross-curricular links:
Topic 8.1—conjugate acid–base pairs
Topic 8.3—the pH concept
Topic 8.4—strong and weak acids and bases
Options B.7 and D.4—buffers

Aims:

- **Aim 6**: The properties of strong and weak acids could be investigated experimentally.

Essential idea: pH curves can be investigated experimentally but are mathematically determined by the dissociation constants of the acid and base. An indicator with an appropriate end point can be used to determine the equivalence point of the reaction.

18.3 pH curves

Nature of science:

Increased power of instrumentation and advances in available techniques—development in pH meter technology has allowed for more reliable and ready measurement of pH. (3.7)

Understandings:

- The characteristics of the pH curves produced by the different combinations of strong and weak acids and bases.
- An acid–base indicator is a weak acid or a weak base where the components of the conjugate acid–base pair have different colours.
- The relationship between the pH range of an acid–base indicator, which is a weak acid, and its pK_a value.
- The buffer region on the pH curve represents the region where small additions of acid or base result in little or no change in pH.
- The composition and action of a buffer solution.

Applications and skills:

- The general shapes of graphs of pH against volume for titrations involving strong and weak acids and bases with an explanation of their important features.
- Selection of an appropriate indicator for a titration, given the equivalence point of the titration and the end point of the indicator.
- While the nature of the acid–base buffer always remains the same, buffer solutions can be prepared by either mixing a weak acid/base with a solution of a salt containing its conjugate, or by partial neutralization of a weak acid/base with a strong acid/base.
- Prediction of the relative pH of aqueous salt solutions formed by the different combinations of strong and weak acid and base.

Theory of knowledge:

- Is a pH curve an accurate description of reality or an artificial representation? Does science offer a representation of reality?

Utilization:

Syllabus and cross-curricular links:

Topic 5.1—thermometric/conductiometric titrations

Topic 16.2—What are the unusual mathematical features of a pH curve? Students should also be familiar with the use of natural logs when using the Arrhenius expression in topic 16.2

Aims:

- **Aim 6**: Experiments could include investigation of pH curves, determination of the pK_a of a weak acid, preparation and investigation of a buffer solution and the determination of the pK_a of an indicator.
- **Aim 7**: Data logging, databases, spreadsheets and simulations can all be used. For example, the equivalence point could be determined by using a conductivity probe or a temperature probe.

18.3 pH curves	
Guidance: • Only examples involving the transfer of one proton will be assessed. Important features are: – intercept with pH axis – equivalence point – buffer region – points where pK_a = pH or pK_b = pOH. • For an indicator which is a weak acid: – $HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$ Colour A Colour B – The colour change can be considered to take place over a range of $pK_a \pm 1$. • For an indicator which is a weak base: – $BOH(aq) \rightleftharpoons B^+(aq) + OH^-(aq)$ Colour A Colour B • Examples of indicators are listed in the data booklet in section 22. • Salts formed from the four possible combinations of strong and weak acids and bases should be considered. Calculations are not required. • The acidity of hydrated transition metal ions is covered in topic 13. The treatment of other hydrated metal ions is not required.	