IB Chemistry II Topic 8 Acids and Bases Review

8.1 Theories of Acids and Bases

1. Define acids and bases according to the following theories:
   Arrhenius, Bronstead-Lowry, Lewis
2. In aqueous solution, sodium hydroxide is a strong base and ammonia is a weak base. Use the Bronsted-Lowry theory to outline why both substances are classified as bases.
3. Sodium hydrogencarbonate dissolves in water forming an alkaline solution according to the following equilibrium:

   HCO_3^- (aq) + H_2O (l) —> H_2CO_3 (aq) + OH^- (aq)

   a) Why is the solution alkaline?
   b) Using the Bronsted-Lowry theory, state, with a brief explanation, whether the HCO_3^- (aq) ion is behaving as an acid or a base.
   c) Identify the conjugate base of carbonic acid, H_2CO_3

4. The simplest amino acid has the structure NH_2CH_2COOH.

   a) Draw its structural formula
   b) Circle and name the two functional groups. Identify them as acidic or basic.
   c) Write the formula for its conjugate acid.

5. Identify the acid/base conjugate pairs for:
   a) $NH_3 + H_2O$ —> $NH_4^+ + OH^-$
   b) $CO_3^{2-} + H_2O$ —> $HCO_3^- + OH^-$
   c) $HNO_3 + H_2O$ —> $NO_3^- + H_3O^+$

6. Substances can act as Bronsted-Lowry acids and/or bases if they give rise to a stable product. Identify the conjugate acid and base form of the following species and identify which of A-E is the most likely to be a Bronsted-Lowry acid or base.

	Conjugate Acid	Conjugate Base
A. CH_4		
B. NH_4		
C. NH_3		
D. H_2O		

7. Consider a weak acid HA dissolved in water:

   HA(aq) + H_2O(l) —> H_3O^+(aq) + A^-(aq)

Which statements are correct?
I. A^-(aq) is a much stronger base than H_2O(l).
II. HA dissociates only to a small extent in aqueous solution.
III. The concentration of H_3O^+(aq) is much greater than the concentration of HA(aq)

8. Which equation represents an acid-base reaction according to Lewis theory **but not** according to Bronsted-Lowry theory?
A. CO_3^{2-}(aq) + $2H^+$(aq) —> H_2O(l) + CO_2(l)
B. Fe^{2+} + 6 H_2O —> [Fe $(H_2O)_6]^{2+}$
C. BaO(s) + H_2O(l) —> Ba^{2+}(aq) + $2OH^-$(aq)
D. NH_3(g) + HCl(g) —> NH_4Cl(s)

8.2 Properties of Acids and Bases

1. List the key properties of acids and bases.
2. Which one of the following substances would an acid not react with?
A. blue litmus paper
B. sodium carbonate
C. magnesium ribbon
D. silver chloride

3. Which one of the following solutions could you distinguish from the others using universal indicator paper?
A. Aqueous ammonia
B. Aqueous sodium chloride
C. Aqueous sodium carbonate
D. Aqueous calcium hydroxide

4. Write balanced equations for the following reactions:
a) iron with dilute sulfuric acid
b) lead carbonate with nitric acid
c) zinc oxide with hydrochloric acid
d) calcium hydroxide with nitric acid
e) sodium hydrogen carbonate with sulfuric acid

5. a) Write the formulae of the oxides of sodium, phosphorus and sulfur
b) Describe their acid/base nature.
c) Write balanced chemical equations for their reactions with water.

6. State the name used to describe a substance that can act as an acid and a base. Using an example illustrate how it can behave as both an acid and a base.

7. A household cleaner contains aqueous ammonia. A 2.447g sample of the cleaner is diluted with water to 20.0cm^3. This solution required 28.51cm^3 of 0.04040 $moldm^{-3}$ sulfuric acid to neutralize all the alkali.
a) Write a balanced chemical equation for the reaction of sulfuric acid with ammonia to form ammonium sulfate.
b) Calculate the amount (moles) of sulfuric acid required for this reaction, and the amount (moles), mass and percentage by mass of ammonia present in the household cleaner.

8. Discuss the acid-base nature of the period three oxides. Write an equation to illustrate the reaction of one of these oxides to produce an acid and another equation of another of these oxides to produce a hydroxide.

9. a) State the bonding in the oxides of sodium, magnesium, silicon and phosphorus.
b) What happens to the pH of pure water when these oxides are added to separate samples of the water? Give equations for any reactions that occur.

8.3 Strong and Weak Acids and Bases

1. Define the terms strong acid and weak acid. Make sure you know properties of strong and weak acids in terms of dissociation, conductivity and reactivity. Using hydrochloric and ethanoic acid as examples, write equations to show the dissociation of each i n aqueous solution. *Be sure you are aware of the other strong and weak acids given in the reading.
2. What is K_a? How does it relate to K_c? What will a strong acid's K_a be? A weak acid?
3. Define the terms strong base and weak base. Make sure you know properties of strong and weak bases in terms of dissociation, conductivity and reactivity. *Be sure you are aware of the other strong and weak acids given in the reading.
4. What is K_b? How does it relate to K_c? What will a strong base's K_b be? A weak base?
5. Contrast strength (of an acid/base) to concentration.
6. Ammonia behaves as a weak base on aqueous solution.
   a) Write a balanced equation for the interaction of ammonia with water.
   b) Using ammonia as an example, explain what is meant by the terms weak and base.
   c) Would you expect a 0.1 mol dm^{-3} solution of ammonia to have a higher or lower pH than a 0.1 mol dm^{-3} solution of sodium hydroxide? Explain.
7. Solutions of nitric acid of the same concentration are prepared. The acids and their equilibrium constants, Kc are:

Acid	Kc (at 25°C) mol dm^{-3}
CH3COOH (aq)	1.7×10^{-5}
HCN	4.0×10^{-10}
HCl	Very large
HF	5.6×10^{-4}

a) Write down the equilibrium constant expression for HCN and its unit. [3]
b) Write down these solutions in order of decreasing pH. [1]
c) Write down these solutions in order of increasing concentration of molecules of acid present in the solution. [1]
d) For the solution of ethanoic acid, write down the formulas of all the chemical species present.

9. Identify one example of a strong acid and one example of a weak acid. Outline three different methods to distinguish between equimolar solutions of these acids in the laboratory. State how the results would differ for each acid. *Make sure you can do the same for a strong and weak base.

8.4 The pH Scale

1. When the pH of a solution changes from 2.0 to 4.0, the hydrogen ion concentration

A. increases by a factor of 100
B. increases by a factor of 2
C. decreases by a factor of 2
D. decreases by a factor of 100

2. Solutions P, Q, R and S have the following properties:

P: pH = 8
Q: [H+] = 1 x 10-3 mol dm-3
R: pH = 5
S: [H+] = 2 x 10-7 mol dm-3

Which of these solutions are arranged in order of increasing acidity (least acidic first), the correct order is

A. P, S, R, Q

B. Q, R, S, P
C. S, R, P, Q
D. R, P, Q, S

3. Lime is added to a lake to neutralize the effects of acid rain. The pH value of the lake water rises from 4 to 7. What is the change in concentration of the hydrogen ions in the lake water?
   A. increase by a factor of 3
   B. increase by a factor of 1000
   C. decrease by a factor of 3
   D. decrease by a factor of 1000

4. The pH of a solution X is 1 and that of Y is 2. Which statement is correct about the hydrogen ion concentration in the two solutions?

A. [H+] in X is half that of Y.
B. [H+] in X is twice that of Y.
C. [H+] in X is one tenth that of Y.
D. [H+] in X is ten times that of Y.

5. Four aqueous solutions, I, II, III and IV, are listed below.
   I. 0.100 mol dm-3 HCl
   II. 0.010 mol dm-3 HCl
   III. 0.100 mol dm-3 NaOH
   IV. 0.010 mol dm-3 NaOH

   What is the correct order of increasing pH of these solutions?

6. 2 H2O (l) ↔ H3O+ (aq) + OH – (aq)
The equilibrium constant for the reaction above is 1.0 x 10-14 at 25°C and 2.1 x 10-14 at 35°C. What can be deduced from this information?
   A. [H3O+] decreases as the temperature is raised
   B. [H3O+] is greater than [OH-] at 35°C
   C. Water is a stronger electrolyte at 25°C
   D. The ionization of water is endothermic

7. The pH values of three acidic solutions X, Y and Z are shown in the following table.

Solution	Acid	pH
X	HCl	2
Y	HCl	4
Z	CH3COOH	4

a) Solutions X and Z have the same acid concentration. Explain by reference to both acids why they have different pH values. [2]
b) Deduce by what factor the values of the hydrogen ion concentration in solutions X and Y differ.

8. Solutions of 0.1 mol dm-3 sodium hydroxide and 0.1 mol dm-3 ammonia have different electrical conductivities.
   a) State and explain which solution has the greatest conductivity. [1]
   b) The pH value of 0.1 mol dm-3 ammonia solution is approximately 11. State and explain how the pH value of the 0.1 mol dm-3 sodium hydroxide solution would compare.