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Subject: Chemistry

Class: Semester-2

Paper: C3T: Inorganic Chemistry

Topic: Acid-Base Reaction

PART 1

Comments: Go through the whole lesson thoroughly.

[**N.B.-** Acknowledgement of indebtedness to Mr. Sibshankar Das, my respected Teacher regarding collection of study materials in Inorganic Chemistry]

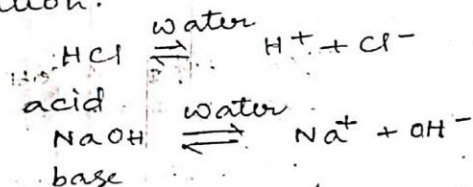
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ACIDS & Bases

Following are the important modern concepts of acids and bases.

1. The Arrhenius concept :-

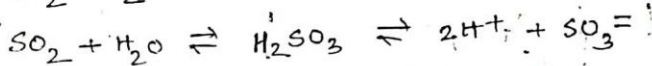
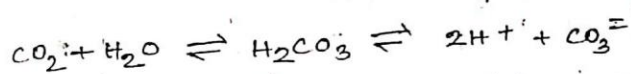
Arrhenius defined an acid as "any H-containing compound which gives H^+ ions in aqueous solution." A base was similarly defined as "any compound which gives hydroxyl ions in aqueous solⁿ." Thus HCl is an acid and NaOH is a base in aqueous solution.



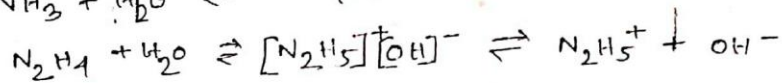
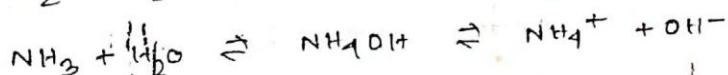
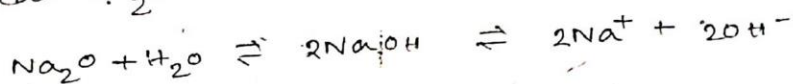
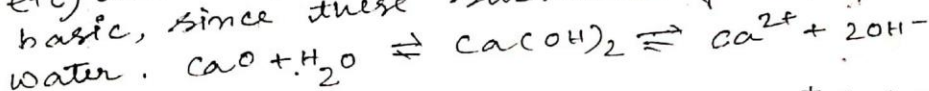
2. Advantages of Arrhenius concept :-

With the help of this concept, we can explain the following;

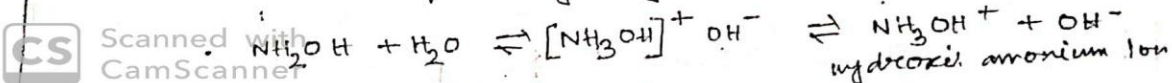
i) Aqueous solution of non-metallic oxides (CO_2, SO_2 etc) is acidic, since it gives H^+ ions in water.



ii) Aqueous solution of metallic oxides (CaO, Na_2O etc) and the compounds like NH_3, N_2H_4, NH_2OH etc are basic, since these substances give OH^- ions in water.



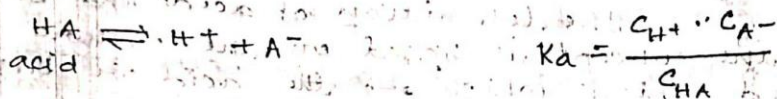
hydrogenium ion



Acids & bases.

iii) This concept can explain the acid-base neutralisation reaction taking place in water.

iv) The strength of an acid (HA) and a base (BOH) can be expressed quantitatively in terms of the dissociation constant of the acid and base in aqueous solution.



v) The catalytic properties of acids in many reactions can be explained by saying that H^+ ions are available from the acid.

→ Limitations of Arrhenius concept:-

In spite of its wide applications in aqueous solution, the Arrhenius theory has certain limitations. These are —

(i) According to this concept, HCl is regarded as an acid only when it is dissolved in H_2O and not in some other solvent such as C_6H_6 or when it exists in the gaseous form.

(ii) It can not account for the acidic and basic character of the materials in non aqueous solvents. eg;

NH_4Cl in liquid ammonia acts as an acid, though it does not give H^+ ions.

(iii) It can not explain the acidic character of certain salts such as AlCl_3 in aq. solⁿ.

iv) The formation of NH_4Cl (s) by the combination of NH_3 (g) and HCl (g) can not be explained by Arrhenius concept.

v) According to this concept, acids and bases undergo dissociation only in water. Thus, it can not explain the dissociation of acids and bases in non aqueous solvents like liquid ammonia, liq SO_2 etc.

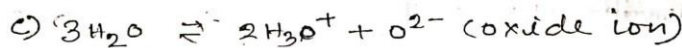
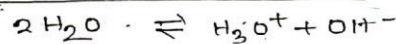
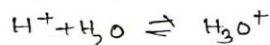
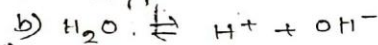
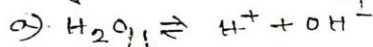
2. The Solvent system concept :-

According to this concept the solvents undergo auto-ionisation and give cations and anions which are called solvent cations and solvent anions respectively.

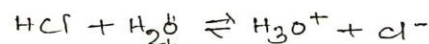
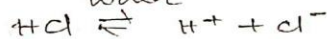
The definition of acids and bases given by this concept is based on the nature of the cations and anions which are the acid or base produces, either by its auto-ionisation or when it is dissolved in this solvent. Thus according to this concept, the substances which give solvent cations when dissolved in that solvent are called acids while the substances which give solvent anions when dissolved in that solvent are called bases. The solvent system concept would be clear, if we consider the auto-ionisation of some solvents like H_2O , liq. NH_3 , liq. SO_2 , liq. HF etc.

Auto-ionisation of water :-

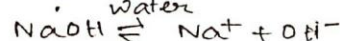
Water undergoes self ionisation in the following three ways.



Therefore according to this concept, the compounds that give H^+ or H_3O^+ ions in H_2O acts as acids while the compounds which give OH^- or O^{2-} ions in H_2O , behave as bases. Since HCl gives H^+ or H_3O^+ ions in water it behaves as an acid in aq. solⁿ.



Similarly, NaOH , which gives OH^- ions in its aq. solⁿ, acts as a base.

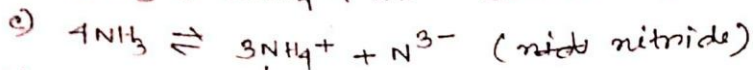
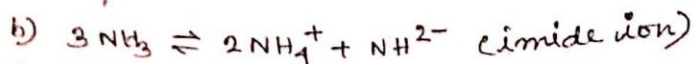
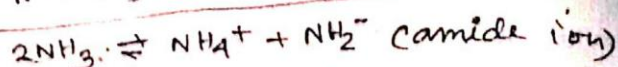
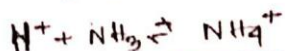


Auto-ionisation of liq. NH_3 :-

liq. NH_3 ionises in the following



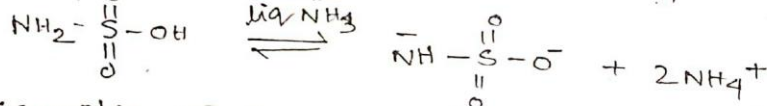
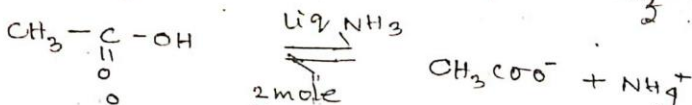
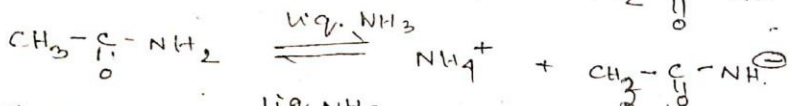
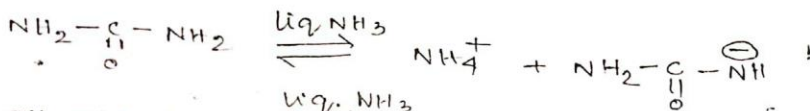
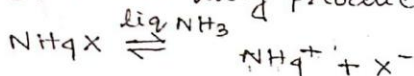
Three ways; - a) $\text{NH}_3 \rightleftharpoons \text{H}^+ + \text{NH}_2^-$



Therefore in liq. NH_3 , any substance that gives NH_4^+ ions will act as an acid in liq. NH_3 , while which produces NH_2^- or NH^{2-} or N^{3-} ions will behave as a base in liq. NH_3 . The compounds which give NH_4^+ ions in liq. NH_3 are called ammono-acids while those which give NH_2^- or NH^{2-} or N^{3-} in this solvent are called ammono bases.

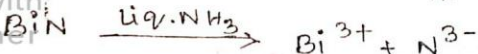
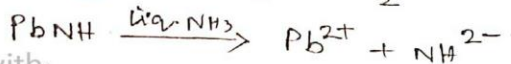
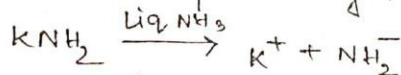
Q. Examples of Ammono Acids :-

Ammonium salts (NH_4Cl , NH_4Br , NH_4I etc), organic amides (urea, acetamide etc), acetic acids, sulphamic acid etc all act as ammono acids in liq. NH_3 , since they produce NH_4^+ ions in this solvent.



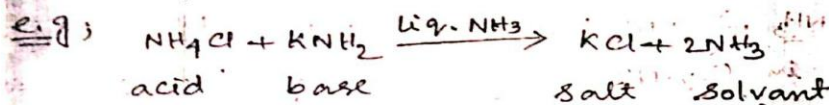
Q. Examples of Ammono Bases :-

KNH_2 , PbNH and BiN are the examples of ammono bases, since these compounds give NH_2^- , NH^{2-} and N^{3-} ions respectively in liq. NH_3 .



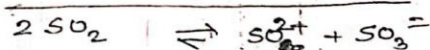
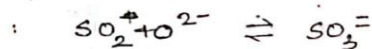
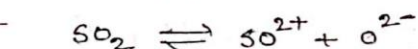
Reaction Between an Ammono Acid and Ammono Base in liq. NH_3 :-

When an ammono acid reacts with an ammono base in liq. NH_3 salts and the solvent are produced.



Q. Auto Ionisation of liq. SO_2 :-

Autoionisation of liq. SO_2 takes place as follows :-



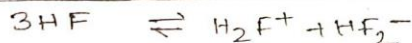
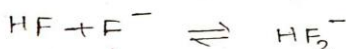
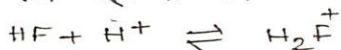
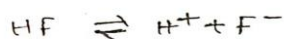
thionyl ion

Thus all the compounds which contain or make available SO^{2+} ions will act as acids in liq. SO_2 . Similarly all the compounds which contain or make available SO_3^{2-} ions, will behave as bases in liq. SO_2 .

In liq. SO_2 , SOCl_2 , SOBr_2 etc. are the acids and K_2SO_3 , Na_2SO_3 are the bases.

Q. Auto-ionisation of liq. HF :-

The high specific conductance of liq. HF suggests the auto-ionisation of liq. HF shown below.



Thus any substance that can give H_2F^+ ions would behave as an acid in liq. HF and any substance that can give HF_2^- ions or F^- ions would act as a base in this solvent.

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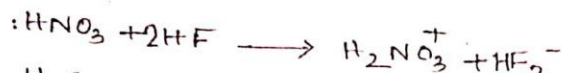
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Examples - (i) CH_3COOH (weak acid in water) acts

as a base in liq. HF, because it gives F^- ions when dissolved in liq. HF.



(ii) H_2SO_4 and HNO_3 , both act as strong acids in aqueous medium but show basic character in liq. HF, due to the production of F^- ions which are solvent anions.



Q. Utility of this concept :-

This concept can be used to explain the acid-base reactions occurring in aq. and non-aqueous solvents.

Q. Limitations or Disadvantages :-

(i) According to this concept the definition of acids and bases is based on the nature of the solvent cation and solvent anion obtained by the auto-ionisation of the solvent.

(ii) It does not explain the acid-base reaction which may occur in the absence of solvent.

(iii) This concept can not explain the acid base reactions occurring in non-ionising solvents like C_6H_6 , $CHCl_3$ etc.

Q. Protonic concept :- (Bronsted-Lowry concept) :-

This theory defined acid as substances or species capable of donating one or more protons. Base was defined as substances or species capable of accepting one or more protons, with no reference to the presence of a solvent. In short, an acid is a proton donor and a base is a proton acceptor.

Substances exhibiting stronger tendency of donating protons are strong acids while weak acids exhibit weaker tendency of releasing proton. Similarly strong bases exhibit stronger tendency of accepting protons while weak bases exhibit

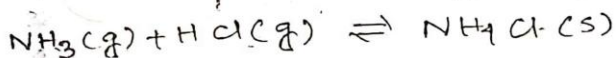
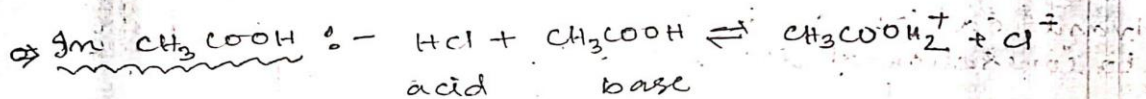
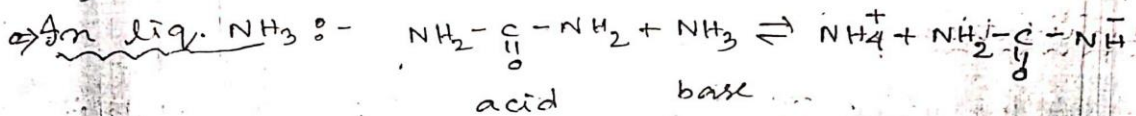
weaker tendency of accepting protons

⇒ Examples :-

Bronsted acid { Molecular :- HCl , H_2SO_4 etc
 Cationic :- NH_4^+ , H_3O^+ , $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ etc
 Anionic :- HCO_3^- , HSO_4^- , HS^- etc.

Bronsted base { Molecular :- NH_3 , H_2O , Pyridine, etc.
 Cationic :- $[\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+}$
 Anionic :- HCO_3^- , HSO_4^- , HS^- etc

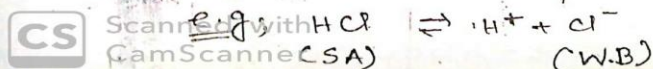
In this concept, acid-base behaviour is applicable in protonic non-aqueous solvents (NH_3 , CH_3COOH etc) and gaseous phase.

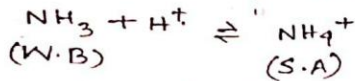
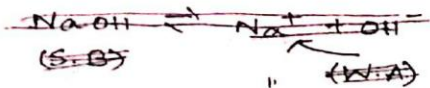
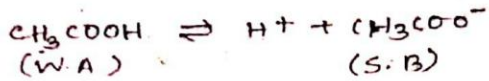


Q. conjugate acid-base pairs :-

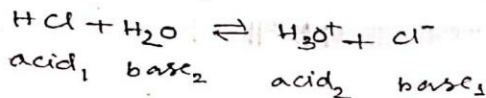
When an acid releases a proton, the species formed exhibit tendency of accepting proton i.e.; basic property. These are called conjugate bases of the acids. Similarly when a base accepts a proton the species formed exhibit acidic property and is called conjugate acid of the base. Thus chemical species that are related to each other in terms of proton release - proton acceptors, are called conjugate to each other.

Strong acids have weak conjugate bases while weak acids have strong conjugate bases. Similarly strong bases have weak conjugate acids, while weak bases have strong conjugate acids.





According to this theory, neutralisation reaction between a pair of acid-base produces a pair of conjugate acid-base.

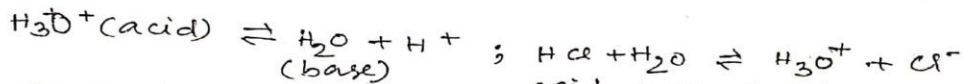


Q. Amphoteric behavior of H₂O :-

According to protonic concept water is amphiprotic or amphoteric. Because it can act both as an acid and a base. When it acts as an acid its conjugate base is OH⁻ ion.



When water acts as a base, its conjugate acid is H₃O⁺ ion.



Q. Some important conjugate acid-base pairs :-

