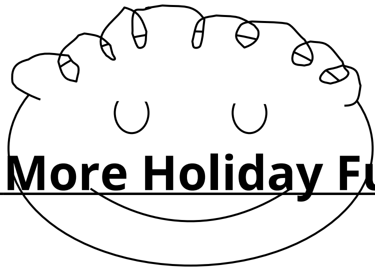

Acids & Bases - 2. - More Holiday Fun

Important Acids

Read text book: 16.4 - Important Acids , pages 343 - 349
(Only Tables 16.4, 16.6 and perhaps 16.7 are relevant to the TEE syllabus)

Read notes: Hydrochloric acid, Sulfuric acid pages 4 - 6

SUMMARY

Answer the following questions.

Chemical properties of hydrochloric acid, sulfuric acid and nitric acid.

1. These three acids react in similar ways with many substances. Complete the following general equations which illustrate these similarities:

acid + carbonate → .... + ... + salt solution

acid + hydrogencarbonate → .... + ... + salt solution

acid + metal oxide → .... + salt solution

acid + metal hydroxide → .... + salt solution

acid + sulfite (SO_3^{2-}) → .... + ... + salt solution

acid + sulfide (S^{2-}) → .... + salt solution

2. The products formed in the reactions of acids with **metals** can vary depending on the acid and its concentration. Complete the following general equations to summarise the products formed for the different acids and concentrations:

hydrochloric acid (all concentrations) + metal → .... + salt solution

dilute sulfuric acid + metal → .... + salt solution

concentrated sulfuric acid + metal → .... + H_2O + salt solution

dilute nitric acid + metal → .... + H_2O + salt solution

concentrated nitric acid + metal → .... + H_2O + salt solution

Industrial Manufacture of Sulfuric Acid

The manufacture of sulfuric acid involves three stages:

1. Production of SO_2
2. Production of SO_3
3. Production of H_2SO_4.

1. Production of SO_2.

a) What are the starting materials for this stage?

b) To form SO_2, the sulfur is burnt in air. Write the equation for this reaction.

(Note - the SO_2 is sometimes obtained from other industries where it is an unwanted, polluting by-product e.g. in the extraction of metals such as copper)

2. Production of SO_3.

a) Give the balanced equation for the formation of SO_3 from SO_2.

b) This reaction is exothermic. Using Le Chatelier's Principle, decide if a high temperature or a low temperature would give you a high yield of SO_3.

c) What conditions, high or low temperature, would allow the reaction to proceed (i.e. the equilibrium position to be reached) at the fastest rate?

d) As you "discovered" in questions b) and c), a high temperature would give you a fast rate but a low equilibrium yield, and a low temperature would give you a high equilibrium yield but at a slow rate. An intermediate temperature of 400°C - 600°C is chosen for the reaction temperature.
At this temperature the reaction is still not 100 % nor does it occur at a very fast rate.

i) What is used to speed up the reaction at his temperature?

ii) How is the yield improved?

e) Considering Le Chatelier's Principle, you would predict that the reaction would be more complete if a high pressure was used. Why is a high pressure not used?

f) Why is it necessary to cool the reaction mixture as it passes from one catalyst bed to another?

g) What precautions are necessary to ensure that the catalyst of V_2O_5 continues to work efficiently?

3. Production of concentrated H_2SO_4.

a) Describe how concentrated sulfuric acid is formed from sulfur trioxide.

b) Give equations for the formation of concentrated H_2SO_4 from SO_3.

c) Why is the sulfur trioxide not just dissolved in water in the industrial production of sulfuric acid?

Important bases

Read text book: 16.5 Important Bases, pages 352 - 357

Read notes: Sodium hydroxide, Ammonia, pages 6 - 7

SUMMARY

Answer the following questions.

Chemical properties of sodium hydroxide.

Complete the following equations, and balance them:

a) reaction of a solution of sodium hydroxide with an acid:

$OH^-(aq) + H^+(aq) \rightarrow$ ....

b) reaction of a solution of sodium hydroxide with an acidic oxide

e.g. $2\ OH^-(aq) + CO_2(g) \rightarrow$ .... + ...

$2\ OH^-(aq) + SO_2(g) \rightarrow$ .... + ...

c) reaction of a solution of sodium hydroxide with amphoteric hydroxides

e.g. $Al(OH)_3(s) + OH^-(aq) \rightarrow$ ....

$Zn(OH)_2(s) + OH^-(aq) \rightarrow$ ....

$Cr(OH)_3(s) + OH^-(aq) \rightarrow$ ....

d) reaction of solution of sodium hydroxide (in excess) with a solution containing a metal ion

e.g. $Cu^{2+}(aq)$ + ... $OH^-(aq) \rightarrow$ ....

$Mg^{2+}(aq)$ + ... $OH^-(aq) \rightarrow$ ....

$Na^+(aq) + OH^-(aq) \rightarrow$ ....

$Al^{3+}(aq)$ + ... $OH^-(aq) \rightarrow$ ....

$Zn^{2+}(aq)$ + ... $OH^-(aq) \rightarrow$ ....

$Cr^{3+}(aq)$ + ... $OH^-(aq) \rightarrow$ ....

$Ni^{2+}(aq)$ + ... $OH^-(aq) \rightarrow$ ....

e) reaction of a solution of sodium hydroxide with amphoteric metals

$Al(s)$ + ...$OH^-(aq)$ + ... $\rightarrow$ .... + ...

$Cr(s)$ + ...$OH^-(aq)$ + ... $\rightarrow$ .... + ...

$Zn(s)$ + ... $OH^-(aq)$ + ... $\rightarrow$ .... + ...

$Cu(s) + OH^-(aq) \rightarrow$

Chemical properties of ammonia

Reaction of a solution of ammonia with a solution containing metal ions

a) when a solution of ammonia is added to most metal ions in solution, the metal ions react with the OH^- ions present in the ammonia solution, to form an insoluble metal hydroxide :

e.g ammonia solution is added to a solution of magnesium chloride

$Mg^{2+}(aq)$ + ... $OH^-(aq) \rightarrow$ ....

ammonia solution is added to a solution of tin nitrate

$Sn^{2+}(aq)$ + ... $OH^-(aq)$ → ....

b) when a solution of ammonia is added to a solution containing Cu^{2+}, Zn^{2+}, or Ag^+, the product formed depends on the amount of ammonia present. First the insoluble metal hydroxide forms, then if more ammonia is present, soluble complex ions containing ammonia molecules form:

e.g. - when ammonia solution is added to a solution of copper sulfate, the following occurs:

$Cu^{2+}(aq) + 2\ OH^-(aq) \rightarrow Cu(OH)_2(s)$ followed by

$Cu(OH)_2(s) + 4NH_3(aq) \rightarrow$ .... $+\ 2\ OH^-(aq)$

(or $Cu^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$)

- when ammonia solution is added to a solution of zinc nitrate, the following occurs:

$Zn^{2+}(aq) + 2\ OH^-(aq) \rightarrow$ .... followed by

$Zn(OH)_2 + 2NH_3(aq) \rightarrow$ .... $+\ 2\ OH^-(aq)$

(or $Zn^{2+}(aq) + 2\ NH_3(aq) \rightarrow [Zn(NH_3)_2]^{2+}(aq)$)

- when ammonia solution is added to a solution of silver nitrate, and precipitate of Ag_2O first forms, and this then dissolves to form $[Ag(NH_3)^{2+}]$

$2\ Ag^+(aq) + 2\ OH^-(aq) \rightarrow$ .... $+\ H_2O(l)$ followed by

$Ag_2O + 2NH_3(aq) + H_2O \rightarrow$ .... $+\ 2\ OH^-(aq)$

(or $Ag^+(aq) + 2\ NH_3(aq) \rightarrow [Ag(NH_3)^{2+}](aq)$)

Industrial Manufacture of Ammonia

(For your exam you must be able to describe in detail the industrial manufacture of ammonia, giving equations, conditions used and reasons for using these conditions, in terms of equilibrium and rates principles. The following questions will help you focus on these ideas.)

The manufacture of ammonia involves only one stage.

a) What are the starting materials for the industrial manufacture of ammonia?

b) From where are these starting materials obtained?

c) Give the balanced equation for the industrial manufacture of ammonia.

d) This reaction is exothermic. Using Le Chatelier's Principle, decide if a high temperature or a low temperature would give you a high yield of ammonia.

e) What conditions, high or low temperature, would allow the reaction to proceed (or the equilibrium position to be reached) at the fastest rate?

f) As was the case in the production of sulfuric acid, a compromise between the use of a low temperature for a maximum yield and a high temperature for faster rate, must be made. An intermediate temperature of about 500ºC is chosen for the reaction temperature. At this temperature the equilibrium yield is still quite low, and the reaction is rather slow.

What is used to speed up the reaction?

g) A high pressure of about 350 atm is also used. Used Le Chatelier's Principle to explain why an increase in pressure would improve the yield of ammonia.

h) Using a high pressure and an intermediate temperature, the reaction is only 30 - 40 % complete. As a result the gases emerging from the catalyst/reaction chamber is a mixture of ammonia, hydrogen and nitrogen gases.

i) How is the ammonia separated from the other two gases?

ii) What happens to the unreacted hydrogen and nitrogen gases after the ammonia has been separated from them?

ANSWERS

Important Acids

Chemical properties of hydrochloric acid, sulfuric acid and nitric acid.

1. acid + carbonate → $\mathbf{CO_2}$ + .$\mathbf{H_2O}$ + salt solution
acid + hydrogencarbonate → $\mathbf{CO_2}$ + .$\mathbf{H_2O}$. + salt solution
acid + metal oxide → $\mathbf{H_2O}$ + salt solution
acid + metal hydroxide → $\mathbf{H_2O}$ + salt solution
acid + sulfite (SO_3^{2-}) → $\mathbf{SO_2}$ + .$\mathbf{H_2O}$ + salt solution
acid + sulfide (S^{2-}) → $\mathbf{H_2S}$ + salt solution

2. hydrochloric acid + metal → $\mathbf{H_2}$ + salt solution
dilute sulfuric acid + metal → $\mathbf{H_2}$ + salt solution
concentrated sulfuric acid + metal → $\mathbf{SO_2}$ + H_2O + salt solution
dilute nitric acid + metal → **NO** + H_2O + salt solution
concentrated nitric acid + metal → $\mathbf{NO_2}$ + H_2O + salt solution

Industrial Manufacture of Sulfuric Acid

1. Production of SO_2.

a) sulfur and oxygen from the air
b) $S(s) + O_2(g) \rightarrow SO_2(g)$

2. Production of SO_3.

a) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
b) If reaction is exothermic, will need to **decrease the temperature** of the system to force it to produce more product. (Or, if decrease temp, the value of the equilib constant will increase i.e. the conc of products must increase - i.e. system moves in forward direction)
c) **High temperature** will increase the reaction rate
d) i) a catalyst called vanadium pentoxide (V_2O_5) is used to speed up the rate at which equilibrium is reached
ii) the reaction mixture is passed over several beds of catalyst
d) As you "discovered" in questions b) and c), a high temperature would give you a fast rate but a low equilibrium yield, and a low temperature would give you a high equilibrium yield but at a slow rate. An intermediate temperature of 400ºC - 600ºC is chosen for the reaction temperature.
At this temperature the reaction is still not 100 % nor does it occur at a very fast rate.
e) It is not necessary because the reaction is almost 100% at atmospheric pressure. (using high pressures is very costly)
f) The reaction is exothermic i.e. the temperature of the reaction mixture will increase as the reaction proceeds. However, the higher the temperature the smaller the yield of product, so it is necessary to keep the temp between approx 400ºC - 600ºC
g) If the catalyst is 'poisoned' by impurities, it will not work efficiently, so it is necessary to have very pure reactants.

3. Production of concentrated H_2SO_4.

a) SO_3 is dissolved in some 98% H_2SO_4 (conc H_2SO_4) to form oleum, and then water is added to produce 98% H_2SO_4
b) $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$
$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$
c) When SO_3 is added to water, a mist/fog of sulfuric acid forms.

Important bases

Chemical properties of sodium hydroxide.

a) $OH^-(aq) + H^+(aq) \rightarrow$.$\mathbf{H_2O(l)}$

b) $2\ OH^-(aq) + CO_2(g) \rightarrow$ $\mathbf{CO_3^{2-}(aq) + H_2O(l)}$
$2\ OH^-(aq) + SO_2(g) \rightarrow$ $\mathbf{SO_3^{2-}(aq) + H_2O(l)}$

c) $Al(OH)_3(s)$ + $OH^-(aq)$ → **$Al(OH)_4^-(aq)$**
$Zn(OH)_2(s)$ + **2** $OH^-(aq)$ → **$Zn(OH)_4^{2-}(aq)$**
$Cr(OH)_3(s)$ + $OH^-(aq)$ → .**$Cr(OH)_4^-(aq)$**

d) $Al_2O_3(s)$ + **2** $OH^-(aq)$ + **$3H_2O(l)$** → **$2Al(OH)_4^-(aq)$**
$Cr_2O_3(s)$ + **2** $OH^-(aq)$ + **$3H_2O(l)$** → **$2Cr(OH)_4^-(aq)$**
$ZnO(s)$ + **2** $OH^-(aq)$ + **$H_2O(l)$** → **$Zn(OH)_4^{2-}(aq)$**

e) $Cu^{2+}(aq)$ + .**2**. $OH^-(aq)$ → **$Cu(OH)_2(s)$**
$Mg^{2+}(aq)$ + **2** $OH^-(aq)$ → **$Mg(OH)_2(s)$**
$Na^+(aq)$ + $OH^-(aq)$ → no reaction
$Al^{3+}(aq)$ + **4** $OH^-(aq)$ → **$Al(OH)_4^-(aq)$**
$Zn^{2+}(aq)$ + **4** $OH^-(aq)$ → **$Zn(OH)_4^{2-}(aq)$**
$Cr^{3+}(aq)$ + **4** $OH^-(aq)$ → **$Zn(OH)_4^{2-}(aq)$**
$Ni^{2+}(aq)$ + **2** $OH^-(aq)$ → **$Ni(OH)_2(s)$**

f) **2** $Al(s)$ + .**2** $OH^-(aq)$ + **6 $H_2O(l)$** → **$2Al(OH)_4^-(aq)$ + $3H_2(g)$**
2 $Cr(s)$ + **2** $OH^-(aq)$ + **6 $H_2O(l)$** → **$2Cr(OH)_4^-(aq)$ + $3H_2(g)$**
$Zn(s)$ + .**2** $OH^-(aq)$ + **2 $H_2O(l)$** → **$Zn(OH)_4^{2-}(aq)$ + $H_2(g)$**
$Cu(s)$ + $OH^-(aq)$ → no reaction (Cu is not amphoteric)

<u>Chemical properties of ammonia</u> - <u>Reaction of a solution of ammonia with a solution containing metal ions</u>

a) $Mg^{2+}(aq)$ + **2** $OH^-(aq)$ → **$Mg(OH)_2$**
$Sn^{2+}(aq)$ + **2** $OH^-(aq)$ → **$Sn(OH)_2$**

b) $Cu^{2+}(aq)$ + 2 $OH^-(aq)$ → $Cu(OH)_2(s)$ followed by
$Cu(OH)_2(s)$ + $4NH_3(aq)$ → **$Cu(NH_3)_4^{2+}(aq)$** + 2 $OH^-(aq)$

$Zn^{2+}(aq)$ + 2 $OH^-(aq)$ → **$Zn(OH)_2(s)$** followed by
$Zn(OH)_2$ + $2NH_3(aq)$ → **$Zn(NH_3)_2^{2+}(aq)$** + 2 $OH^-(aq)$

2 $Ag^+(aq)$ + 2 $OH^-(aq)$ → $Ag_2O(s)$ + $H_2O(l)$ followed by
Ag_2O + $2NH_3(aq)$ + H_2O → **$Ag(NH_3)^{2+}(aq)$** + 2 $OH^-(aq)$

<u>Industrial Manufacture of Ammonia</u>

a) nitrogen and hydrogen gases

b) nitrogen - from the air (by fractional distillation)
hydrogen - from the petroleum industry, e.g. from methane, CH_4

c) $N_2(g)$ + $3H_2(g)$ → $2NH_3(g)$

d) If reaction is exothermic, will need to **decrease the temperature** of the system to force it to produce more product. (Or, if decrease temp, the value of the equilib constant will increase i.e. the conc of products must increase - i.e. system moves in forward direction)

e) **High temperature** will increase the rate at which equilibrium is reached

f) An iron/iron oxide catalyst is used

g) If the pressure is increased, the system will move to try to decrease the pressure, by producing a smaller number of particles i.e. it will move towards the right i.e. produce more NH_3

h) i) The mixture of gases is cooled, and because NH_3 has a lower boiling point than N_2 or H_2, it becomes a liquid 'first'

ii) they are returned to the reaction chamber