EUROPEAN UNION
MINISTRY OF EDUCATION, YOUTH AND SPORTS
OP Education for Competitivness
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

CHEMICAL REACTIONS

Chemical reaction = process during which original substances change to new substances, reactants turn to .... The bonds of reactants .... and new bonds are................

The classification of reactions:

1. Classification according to the heat exchange
   - **endothermic** – heat is ...., molar heat of the reaction Q_m 0 kJ·mol^{-1}
   - **exothermic** – heat is ...., molar heat of the reaction Q_m 0 kJ·mol^{-1}

   1. Give examples of endothermic and exothermic reactions.

2. An old classification of inorganic reactions
   - **..........................**: two or more reactants form one product $Na + Cl_2 \rightarrow$
   - **..........................**: one reactant decomposes to two or more products: $HgO \rightarrow$
   - **..........................**: one element displaces another from a compound: $Zn + H_2SO_4 \rightarrow$
   - **double exchange**: ....: $AgNO_3 + NaCl \rightarrow$

3. Classification of reactions in organic chemistry
   - **addition**: $CH_2{=}CH_2 + HCl \rightarrow CH_3\text{-}CH_2Cl$
   - **elimination**: $CH_3\text{-}CH_2OH \rightarrow H_2O + CH_2{=}CH_2$
   - **substitution**: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
   - **intramolecular transfer/ conversion**: $CH_3\text{-}CH{=}CH\text{-}OH \rightarrow CH_3\text{-}CH_2\text{-}CH{=}O$

4. Classification according to the phases of the reactants and the products

   s = solid, l = liquid, g = gas, aq = aqueous solution

   - **homogeneous**: all substances are in the .... phase, e.g. in a solution

     $NaOH(aq) + HCl(aq) \rightarrow$

   - **......................**:reactants and products are in at least ....phases:

     $2HCl(aq) + CaCO_3(s) \rightarrow$

   Precipitation reactions: reactants are in an aqueous ...., they react together to make at least one substance which is .... in water = **precipitate**. The symbol of a precipitate is ....

   $AgNO_3(aq) + NaCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$

   Eliminating identical ions on both sides of the equation:

   … **ionic equation** of a precipitation reaction

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5. Classification according to the type of the transferred particle

- **Redox reactions** – transfer of ....: $Fe^0(s) + Cu^{II}SO_4(aq) \rightarrow Cu^0(s) + Fe^{II}SO_4(aq)$
  half equations: Fe^0............. → Fe^{2+} Cu^{2+}.......... → Cu^0
- **Acid-base reactions** – transfer of ....
  $HCl(aq) + NaOH(aq) \rightarrow$ ....(l) + ...(aq)
- **Coordination reactions** (complex forming) – transfer of atoms or of groups of atoms
  $CuSO_4 + 4H_2O \rightarrow [Cu(H_2O)_4]SO_4$
  $[Cu(H_2O)_4]SO_4 + 4NH_3 \rightarrow [Cu(NH_3)_4]SO_4 + 4H_2O$
  Lone pairs of electrons of water (resp. ammonia) molecules form dative (coordinate) bond with empty orbitals on Cu^{2+} ion.

<u>**Redox reactions**</u>

= transfer of ....
Gain of electrons = **.....................**, loss of electrons = **.........................**.
Substance donating electrons = **.................. agent**, substance accepting electrons = **................. agent**.
Each redox reaction may be separated to two half reactions:

  2 HCl + Zn →

2. *Finish the equation, write down the oxidation numbers of all atoms in the equation, find what is oxidised and what is reduced and write down the equations for the half reactions.*

Oxidation:
Reduction: … half equations

Half equations are used to balance equations of redox reactions using the fact that the number of electrons .... during oxidation is .... as the number of electrons .... during reduction.

Balancing equations of redox reactions

<u>Worked example:</u> Balance the following equation:

$$FeCl_2 + K_2Cr_2O_7 + HCl \rightarrow FeCl_3 + CrCl_3 + KCl + H_2O$$

1. step: give the oxidation numbers of all atoms
2. step: find out what atoms take part on the redox process and balance their numbers if necessary.
3. step: write down the half equations and balance the number of electrons

oxidation:

reduction:

4. step: balance the number of oxidised and reduced atoms in the original equation

5. step: use the number of atoms in already balanced compounds to balance the rest of the atoms.

6. step: To check whether the balancing is correct the number of atoms of that element which was not used in the steps 4 and 5 in reactants and products may be checked.

3. *Balance the following equations:*

a.	$Cr_2O_3 + KNO_3 + KOH \rightarrow K_2CrO_4 + KNO_2 + H_2O$	a.	1,3,4 → 2,3,2
b.	$FeSO_4 + KMnO_4 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + K_2SO_4 + MnSO_4 + H_2O$	b.	10,2,8 → 5,1,2,8
c.	$MnO_2 + KClO_3 + KOH \rightarrow K_2MnO_4 + KCl + H_2O$	c.	3,1,6 → 3,1,3
d.	$S + HNO_3 \rightarrow H_2SO_4 + NO$	d.	1,2 → 1,2
e.	$HI + H_2SO_4 \rightarrow I_2 + H_2S + H_2O$	e.	8,1 → 4,1,4
f.	$BiCl_3 + SnCl_2 \rightarrow Bi + SnCl_4$	f.	2,3 → 2,3
g.	$FeCl_3 + H_2S \rightarrow FeCl_2 + S + HCl$	g.	2,1 → 2,1,2
h.	$Se + Cl_2 + H_2O \rightarrow H_2SeO_3 + HCl$	h.	1,2,3 → 1,4
i.	$HClO + Br_2 + H_2O \rightarrow HBrO_3 + HCl$	i.	5,1,1 → 2,5
j.	$As_2O_3 + Br_2 + H_2O \rightarrow H_3AsO_4 + HBr$	j.	1,2,5 → 2,4
k.	$HI + HBrO_3 \rightarrow I_2 + H_2O + HBr$	k.	6,1 → 3,3,1
l.	$HIO_3 + H_2SO_4 + FeSO_4 \rightarrow I_2 + Fe_2(SO_4)_3 + H_2O$	l.	2,5,10 → 1,5,6
m.	$H_2SO_3 + I_2 + H_2O \rightarrow H_2SO_4 + HI$	m.	1,1,1 → 1,2
n.	$KClO_3 + KI + H_2SO_4 \rightarrow K_2SO_4 + KCl + I_2 + H_2O$	n.	1,6,3 → 3,1,3,3
o.	$H_2SO_3 + HClO_4 \rightarrow HCl + H_2SO_4$	o.	4,1 → 1,4
p.	$HIO_3 + CO \rightarrow CO_2 + I_2 + H_2O$	p.	2,5 → 5,1,1
q.	$C + H_2SO_4 \rightarrow CO_2 + SO_2 + H_2O$	q.	1,2 → 1,2,2
r.	$I_2 + HNO_3 \rightarrow HIO_3 + NO + H_2O$	r.	3,10 → 6,10,2
s.	$FeSO_4 + HNO_3 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + NO + H_2O$	s.	6,2,3 → 3,2,4
t.	$As_2O_3 + HNO_3 + H_2O \rightarrow H_3AsO_4 + N_2O_3$	t.	1,2,2 → 2,1

ACID-BASE REACTIONS

Acids and bases

These substances are known for many years and their names often describe their origin.

4. *Name some acids and bases you know.*

5. *What acid is a component of gastric juice?*

Arrhenius theory:

acids = substances which are able to **donate .....** ions in aqueous solutions:

$HNO_3 \rightarrow$ ..... + NO_3^-

bases = hydroxides = substances which are able to **donate .....** ions in aqueous solutions:

$NaOH \rightarrow Na^+$ + ...

When H^+ a OH^- react together .... is formed and a .... is produced from the metal cation and the acid anion.

A reaction between an acid and a hydroxide is called ....

$HNO_3 + NaOH \rightarrow$ .... + ...

6. *What is the first aid when somebody is etched with an acid or a hydroxide?*
7. *What is the label for dangerous corrosive substances?*

So that a substance shows its either acidic or basic character it is necessary to take on account also the solvent. That is why a new theory was introduced.

Bröndsted- Lowry theory (the most used)

acids = substances which .... a proton (H^+) = **proton ....**

bases = substances which .... a proton = **proton ....**

Acid-base reactions = **protolytic reactions** = transfer of H^+ (protons)

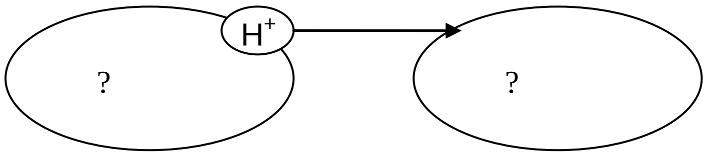
When proton is given out from an acid its conjugate .... is formed.

When proton is accepted by a base its conjugate .... is formed.

$HClO + H_2O \rightleftarrows H_3O^+ + ClO^-$ $\qquad$ $H_2O + NH_3 \rightleftarrows OH^- + NH_4^+$

The conjugate base of a strong acid is weak and the opposite way round.

8. *Substitute the question marks with the words ACID and BASE.*



Conjugate pair = a pair of substances which differ by .... (acid + base)

9. *Find the pairs which differ by H^+ and connect them:*

$HNO_2 + H_2O \rightleftarrows H_3O^+ + NO_2^-$ $\qquad$ $H_2O + PH_3 \rightleftarrows OH^- + PH_4^+$

10. *Find the conjugate pairs in the following general equation and connect them:*

ACID 1 + BASE 2 ⇄ ACID 2 + BASE 1

Acids and bases are not neutral molecules only.

11. *Write down the half equations of accepting and donating protons for the underlined examples of acids and bases*

Acids: $\underline{HCl}$, H_2SO_4, HSO_4^-, $\underline{H_3PO_4}$, $\underline{H_2PO_4^-}$, HPO_4^{2-}, $\underline{H_2O}$, NH_4^+, $\underline{H_3O^+}$, CH_3COOH

Bases: Cl^-, $\underline{HSO_4^-}$, SO_4^{2-}, $\underline{H_2PO_4^-}$, HPO_4^{2-}, $\underline{PO_4^{3-}}$, $\underline{H_2O}$, $\underline{OH^-}$, NH_3, CH_3COO^-

HCl	HSO_4^-
H_3PO_4	$H_2PO_4^-$
$H_2PO_4^-$	PO_4^{3-}
H_2O	H_2O
H_3O^+	OH^-

Some substances may act both as an acid and a base = **........................... substances**.

12. *Choose from the above examples of acids and bases amphoteric molecules or ions.*

The transfer of H^+ may happen between the molecules of the solvent. The solvent behaves both as an .... and as a .... This is called .... of the solvent.

13. *Find the conjugate pairs in the following equations:*

$H_2O + H_2O \rightleftarrows H_3O^+ + OH^-$ $\qquad$ $NH_3 + NH_3 \rightleftarrows NH_4^+ + NH_2^-$

14. *What is the conjugate acid of: a. CH_3COO^- b. HSO_4^- c. NH_3 d. OH^-*

15. *What is the conjugate base of: a. HCl b. H_3O^+ c. HSO_4^- d. NH_4^+*

The strength of acids and bases

Acids resp. bases differ in the extent to which they donate resp. accept ....

Strong acids donate protons easily, they donate all their protons. H^+ ion does not exist separately it binds to water molecules forming .... ion (H_3O^+)

16. *Underline the particles which can be found in aqueous solution of HCl: HCl, H_2O, Cl^-, H_3O^+, H^+.*

Strong acids are:

- hydrohalic acids with the exceptions of HF (weak)
- inorganic oxoacids with the general formula H_nXO_{n+2}: ...., ... or H_nXO_{n+3}: $HClO_4$ (X = non-metal)

The strength of <u>oxoacids</u> increases with increasing difference between the number of oxygen and hydrogen atoms in their molecules.

Weak acids have little tendency to donate protons. Relatively few molecules will donate H^+ ions to water, a big deal of their molecules is undissociated.

17. *Underline the particles which can be found in aqueous solution of CH_3COOH: H_3O^+, CH_3COO^-, CH_3COOH, H_2O , H^+.*

Weak acids are:

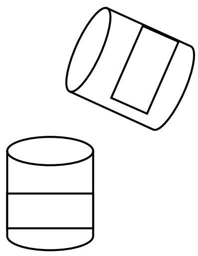
- organic acids like: ...., ..., ..., ...
- inorganic oxoacids with the general formula H_nXO_n :…………
- some binary acids: ...., ...

Strong bases accept protons easily, e.g. $OH^- + H^+ \rightarrow$ ....

Strong bases are hydroxides of alkali metals and alkaline earth metals: ....

Weak bases have little tendency to accept protons.

18. *Which of the following particles may be found in the aqueous solution of ammonia NH_3? NH_3, NH_4^+, OH^-, H_2O*



19. *Fill the labels in the picture and explain how to dilute an acid.*

The temperature is *increasing/decreasing* during a dilution of an acid.

<u>The ionisation /dissociation of water</u>

Even pure water has a tiny el. conductivity. This is the evidence that water dissociate to form ions.

$H_2O(l) \rightleftarrows$ ....(aq) + ...(aq)

$H_2O(l) + H_2O(l) \rightleftarrows$ ....(aq) + ...(aq)

In a neutral pure water at the temperature of 25°C: $c(H_3O^+) = c(OH^-) = 10^{-7}$ $mol{\cdot}dm^{-3}$.

$c(H_3O^+) \times c(OH^-)$ = ... $mol^2{\cdot}dm^{-6}$ = ionic .... of water = ...

The value of ionic product of water is a constant for all aqueous solutions in standard conditions .

When $c(H_3O^+)$ is increased by adding an .... (....... + $H_2O \rightarrow H_3O^+$ + ...) the concentration of OH^- is .... as they combine with the excess of H_3O^+ to form ....($OH^- + H_3O^+ \rightarrow$ ....).

And vice versa. When $c(OH^-)$ is increased by adding a .... (............. $\rightarrow$ .... + OH^-) the concentration of H_3O^+ is .... as they combine with the excess of OH^- to form ....

Thus the $c(H_3O^+) \times c(OH^-)$ stays constant .... $mol^2{\cdot}dm^{-6}$

Solutions are classified according to the same or different values of concentrations of oxonium and hydroxide ions as ...., ... or ....

20. *Fill <,> or = into the second column and acidic, alkaline or neutral to the third column of the table.*

$c(H_3O^+) > c(OH^-)$	$c(H_3O^+)$ ..... 10^{-7} $mol{\cdot}dm^{-3}$	
	$c(OH^-)$ .....10^{-7} $mol{\cdot}dm^{-3}$	
$c(H_3O^+) = c(OH^-)$	$c(H_3O^+)$ ......10^{-7} $mol{\cdot}dm^{-3}$	
	$c(OH^-)$ .....10^{-7} $mol{\cdot}dm^{-3}$	
$c(H_3O^+) < c(OH^-)$	$c(H_3O^+)$ ..... 10^{-7} $mol{\cdot}dm^{-3}$	
	$c(OH^-)$ .....10^{-7} $mol{\cdot}dm^{-3}$	

The pH scale

pH is a measure of the extent of acidity of a solution defined:

$pH = -\log c_{H3O+}$ $\qquad c_{H3O+} = 10^{-3}$ $mol{\cdot}dm^{-3} \Rightarrow$ pH = ...

$c_{H3O+} = 10^{-8}$ $mol{\cdot}dm^{-3} \Rightarrow$ pH = ...

$c_{H3O+} = 0.01\ mol{\cdot}dm^{-3} = 10^{-....}\ mol{\cdot}dm^{-3} \Rightarrow pH = ...$

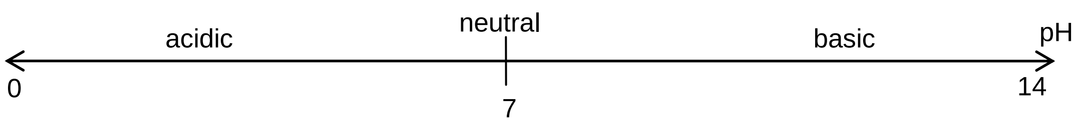
$c_{H3O+} = 0.02\ mol{\cdot}dm^{-3} \Rightarrow$ use a calculator $\Rightarrow pH = ...$

21. *Fill the following table using:*

$pH = -\log c_{H3O+}$, $c_{H3O+} \times c_{OH-} = 10^{-14}\ mol^2{\cdot}dm^{-6}$, $c_{H3O+} = 10^{-pH}$ and $pOH = -\log c_{OH-}$.

c_{H30+}	0.1			0.05			
c_{OH-}			10^{-6}		1.5×10^{-5}		
pH		10				2.5	
pOH							2
A, N, B							

22. *What is the relationship between pH and pOH?*
23. *Classify the above solutions as acidic, neutral and basic (alkaline).*

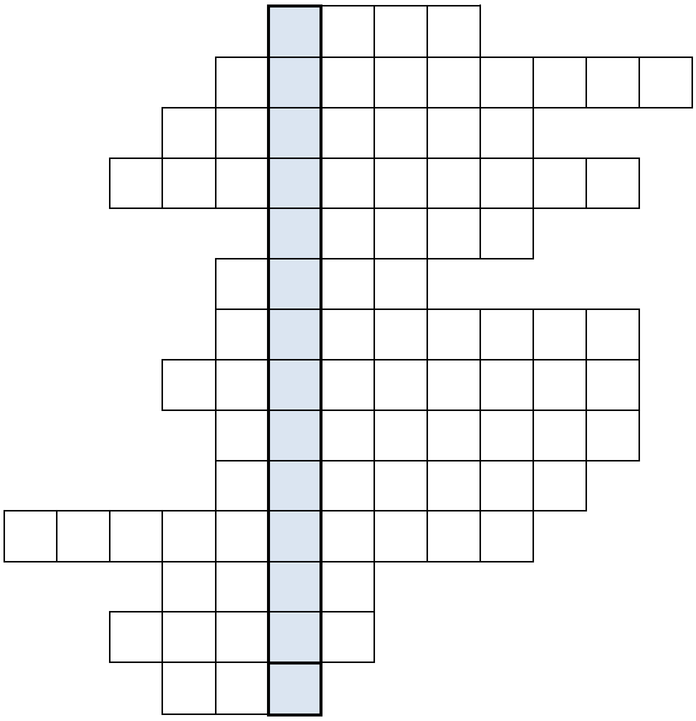


24. *Explain the term "neutral solution" on the basis of dissociation of water.*

25. *Estimate whether the following substances are alkaline, acidic or neutral, confirm your decision with the help of the pH paper.*

Substance	*Estimated pH*	*Measured pH*
Mineral water		
Soap solution		
Vinegar		
Coca-cola		
Salty water		
Saliva		
Citric juice		
Vitamin C		
Distilled water		
Your own sweat		

26. Solve the crossword



Sodium hydroxide
Decreasing of oxidation number
Atomic particle without a charge
Separating solid from a liquid
An element with Z = 86
Substance accepting H^+
A negatively charged atomic particle
Increasing of oxidation number
Atoms with the same Z and different A
A discoverer of a neutron
Both acidic and basic
Substance liberating H^+
Carbonic acid
Charged particles made of atoms

pH of strong acids

Worked example: Calculate the pH of 0.01M solution of hydrochloric acid.

c_{HCl} = 0.01 mol·dm^{-3}	pH = − log c_{H3O+}
<u>HCl</u> + H_2O →	pH =
	pH =
⇒ c_{H3O+} =	pH =

Worked example: Calculate the pH of 0.01M solution of sulphuric acid.

c_{H2SO4} = 0.01 mol·dm^{-3}	pH = − log c_{H3O+}
H_2SO_4 is a strong diprotic acid	pH =
It liberates two H^+ ions.	pH =
<u>H_2SO_4</u> + $2H_2O$ →	pH =

⇒ c_{H3O+} =

Strong monoprotic acids: HCl, HBr, HI, HNO_3,… ⇒ pH =−log c_{HA}

Strong diprotic acids: H_2SO_4 ⇒ pH = −log(2 × c_{H2A})

27. Calculate the pH for the following solutions:

a. HBr, c_{HBr} = 2.25 × 10^{-3} mol·dm^{-3}

b. HNO_3, $c_{HNO3} = 0.001$ mol·dm^{-3}

c. H_2SO_4, $c_{H2SO4} = 5 \times 10^{-2}$ mol·dm^{-3}

28. *10 cm^3 of hydrogen iodide (gaseous) was dissolved in water and made up to 500 cm^3. Calculate the pH of this solution. (The volume of HI(g) is measured at s.t.p.)*
29. *350 cm^3 of H_2SO_4 solution contains 1 g of pure H_2SO_4. Calculate the pH of this solution.*

pH of strong hydroxide solutions

Worked example: Calculate the pH of 0.01M NaOH solution.

$c_{NaOH} = 0.01$ mol·dm^{-3}	pOH = − log c_{OH-}	pH = 14 − pOH
NaOH →	pOH =	pH =
	pOH =	pH =
⇒ c_{OH-} =	pOH =	

Worked example: Calculate the pH of 0.01M $Ba(OH)_2$ solution.

$c_{Ba(OH)2} = 0.01$ mol·dm^{-3}	pOH = −log c_{OH^-}	pH = 14 − pOH
$Ba(OH)_2$ →	pOH =	pH =
	pOH =	pH =
⇒ c_{OH^-} =	pOH =	

Strong hydroxides with 1 OH^- ion: NaOH, KOH ⇒ pH = 14 + log c_{MOH}

Strong hydroxides with 2 OH^- ions: $Ba(OH)_2$ ⇒ pH = 14 + log (2 × $c_{M(OH)2}$)

30. *Calculate the pH of the following solutions:*
    a. *0.03 M KOH*
    b. *0.1 M NaOH*
    c. *0.005 M $Ba(OH)_2$*
31. *16 g of sodium hydroxide was dissolved in water and made up to 400 cm^3. Calculate the pH of this solution.*
32. *0.1 g of barium hydroxide was dissolved in water and made up to 1.5 dm^3. Calculate the pH of this solution.*

33. *What is the pH of a solution made by dissolving 7.41 g of lithium hydroxide to 8 dm^3 of a solutiuon?*
34. *What is the pH of 1% solution of $HClO_4$ ($\rho = 1.06$ g·cm^{-3})?*
35. *What is the pH of HCl solution of the concentration c = 0.15 mol/l?*

36. *What is the molar concentration of a barium hydroxide solution of the pH = 11?*

37. *What is the molar concentration of an HCl solution of the pH = 4.2?*

38. *What is the molar concentration of a solution of KOH of the pH = 10.5?*

Salt hydrolysis

= reaction between ions of a salt and molecules of water

1. salts of strong acids and weak bases

e.g. NH_4Cl dissolves in water to form NH_4^+ and Cl^- ions

Cl^- don't react with water

$NH_4^+ + H_2O \rightleftarrows$ .... $\Rightarrow$ NH_4^+ increase the concentration of .... $\Rightarrow$ *basic/acidic* solution

2. salts of weak acids and strong bases

e.g. $CH_3COONa \rightarrow$

Na^+ don't react with water

$CH_3COO^- + H_2O \rightleftarrows$ .... $\Rightarrow$ CH_3COO^- increase the concentration of .... $\Rightarrow$ *basic/acidic* solution

3. salts of strong acids and strong bases

e.g. $NaCl \rightarrow$

Neither Na^+ nor Cl^- don't react with water $\Rightarrow$ .... solution

4. salts of weak acids and weak bases

e.g. $CH_3COONH_4 \rightarrow$

$CH_3COO^- + H_2O \rightleftarrows$ ....

$NH_4^+ + H_2O \rightleftarrows$ ....

OH^- react with H_3O^+ to form .... $\Rightarrow$ .... solution

39. *Classify the solutions of the following compounds as acidic, basic or neutral:Na_2S, $Ba(NO_3)_2$, KCl, $(NH_4)_2CO_3$, $CuSO_4$, $Zn(NO_3)_2$, K_2SO_3, Na_2SO_4*

Acid-base indicators

Indicator = a weak acid whose conjugate base is a different colour

$HInd + H_2O \rightleftarrows H_3O^+ + Ind^-$

colour A colour B

40. *What colour forms of an indicator will be observed in the following cases?*

a. $HInd + OH^- \rightarrow$

b. $HInd + H_3O^+ \rightarrow$

c. $Ind^- + OH^- \rightarrow$

d. $Ind^- + H_3O^+ \rightarrow$

The most common indicators:

	Colour in acidic conditions	Colour in alkaline conditions
Phenolphthalein		
Litmus		
Methylorange		
Bromothymol blue		

Lewis theory of acids and bases

Lewis acid = electron pair acceptor

Lewis base = electron pair donor

Lewis acids include Bröndsted acids and Lewis bases include Bröndsted bases.

$H^+ + |NH_3 \rightarrow NH_4^+$

$H^+ + |\overline{\underline{O}}H^- \rightarrow H_2O$

H^+ is both Bröndsted acid and Lewis acid, NH_3 and OH^- are both Bröndsted bases and Lewis bases.

However, Lewis acids include many substances other than proton donors.

$BF_3 + |NH_3 \rightarrow BF_3NH_3$

BF_3 is Lewis acid as it is an electron pair acceptor.

41. Draw the electronic formula of BF_3NH_3.

Basic types of acid-base reactions

1. **Neutralization: acid + hydroxide → salt + water**

   $H_2SO_4 + Ca(OH)_2 \rightarrow$

   $HNO_3 + KOH \rightarrow$

   $HCl + NaOH \rightarrow$

2. **Acid + metal oxide → salt + water**

   $H_2SO_4 + CaO \rightarrow$

   $HCl + Al_2O_3 \rightarrow$

   $HNO_3 + MgO \rightarrow$

3. **Strong acid + weak acid salt → strong acid salt + weak acid**

   Strong acid displaces a weak acid from its salt.

   $H_2SO_4 + Ca(NO_2)_2 \rightarrow$

   $HClO_4 + CH_3COONa \rightarrow$

In the case that the weak acid is unstable it decomposes to its oxide and water.

$H_2SO_4 + CaCO_3 \rightarrow$

$HCl + Na_2SO_3 \rightarrow$

4. Hydroxide + non-metal oxide → salt + water

$Ca(OH)_2 + SO_2 \rightarrow$

$KOH + CO_2 \rightarrow$

5. Strong base + weak base salt → strong base salt + weak base

Strong base displaces a weak base from its salt.

$NaOH + CuCl_2 \rightarrow$

In the case that the product is ammonium hydroxide, it partialy decomposes to ammonia and water, we may write also: $NaOH + NH_4Cl \rightarrow$

42. Finish the following equations:

a. $HCl + CuO \rightarrow$
b. $NaOH + CO_2 \rightarrow$
c. $H_2SO_4 + K_2SO_3 \rightarrow$
d. $HNO_3 + NH_4OH \rightarrow$
e. $KOH + (NH_4)_2SO_4 \rightarrow$
f. $HClO_4 + Fe_2O_3 \rightarrow$
g. $HCl + Na_2S \rightarrow$
h. $H_3PO_4 + NaOH \rightarrow$
i. $NaOH + CuSO_2 \rightarrow$
j. $KOH + SO_2 \rightarrow$
k. $CuO + H_2SO_4 \rightarrow$
l. $H_2SO_4 + Na_2S \rightarrow$
m. $Ba(OH)_2 + CO_2 \rightarrow$
n. $NH_4NO_3 + NaOH \rightarrow$
o. $CO_2 + KOH \rightarrow$
p. $HCl + NaHCO_3 \rightarrow$
q. $HClO_4 + NaOH \rightarrow$
r. $CO_2 + Ca(OH)_2 \rightarrow$
s. $FeO + HNO_3 \rightarrow$
t. $Na_2SO_3 + HCl \rightarrow$