Chapter 11

Chemical Reactions

1

All chemical reactions

- **have two parts**
- **Reactants - the substances you start with**
- **Products- the substances you end up with**
- **The reactants turn into the products.**
- **Reactants → Products**

2

In a chemical reaction

- **The way atoms are joined is changed**
- **Atoms aren't created or destroyed.**
- **Can be described several ways**
- **In a sentence**
  - **Copper reacts with chlorine to form copper (II) chloride.**
- **In a word equation**
- **Copper + chlorine → copper (II) chloride**

3

Symbols used in equations

- **Table 11.1**
- **the arrow separates the reactants from the products**
- **Read "reacts to form"**
- **The plus sign = "and"**
- **(s) after the formula -solid**
- **(g) after the formula -gas**
- **(l) after the formula -liquid**

4

Symbols used in equations

- **(aq) after the formula - dissolved in water, an aqueous solution.**
- **↑ used after a product indicates a gas (same as (g))**
- **↓ used after a product indicates a solid (same as (s))**

5

Symbols used in equations

- **⇌ indicates a reversible reaction (More later)**
- **shows that heat is supplied to the reaction**
- **is used to indicate a catalyst used in this case, platinum.**

6

What is a catalyst?

- **A substance that speeds up a reaction without being changed by the reaction.**
- **Enzymes are biological or protein catalysts.**

7

Skeleton Equation

- **Uses formulas and symbols to describe a reaction**
- **doesn't indicate how many.**
- **All chemical equations are sentences that describe reactions.**

8

Convert these to equations

- **Solid iron (III) sulfide reacts with gaseous hydrogen chloride to form solid iron (II) chloride and hydrogen sulfide gas.**

9

Convert these to equations

- **Nitric acid dissolved in water reacts with solid sodium carbonate to form liquid water and carbon dioxide gas and sodium nitrate dissolved in water.**

10

The other way

- **$Fe(g) + O_2(g) \rightarrow Fe_2O_3(s)$**

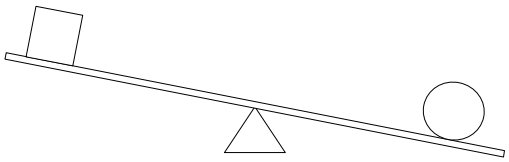
11

The other way

- **$Cu(s) + AgNO_3(aq) \rightarrow Ag(s) + Cu(NO_3)_2(aq)$**

12

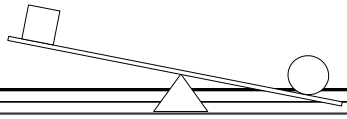
Balancing Chemical Equations



13

Balanced Equation

- **Atoms can't be created or destroyed**
- **All the atoms we start with we must end up with**
- **A balanced equation has the same number of atoms of each element on both sides of the equation.**



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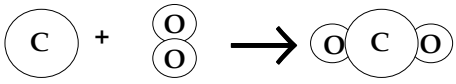
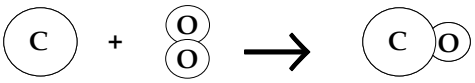


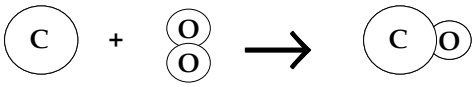
- **$C + O_2 \rightarrow CO_2$**
- **This equation is already balanced**
- **What if it isn't already?**

15



- **$C + O_2 \rightarrow CO$**
- **We need one more oxygen in the products.**
- **Can't change the formula, because it describes what actually happens**

16



- **Must be used to make another CO**
- **But where did the other C come from?**
- **Must have started with two C**
- **$2\ C + O_2 \rightarrow 2\ CO$**

17

Rules for balancing

1. **Write the correct formulas for all the reactants and products**
2. **Count the number of atoms of each type appearing on both sides**
3. **Balance the elements one at a time by adding coefficients (the numbers in front)**
4. **Check to make sure it is balanced.**

18

Never

- **Change a subscript to balance an equation.**
  - **If you change the formula you are describing a different reaction.**
  - **H_2O is a different compound than H_2O_2**
- **Never put a coefficient in the middle of a formula**
  - **2 NaCl is okay, Na2Cl is not.**

19

Example

$2\,H_2 + O_2 \rightarrow H_2O$ **$2\,H_2O$**

R		P
4	H	4
2	O	2

[illegible] are the same

20

Example

~~Example~~

$2\,H_2 + O_2 \rightarrow 2\,H_2O$

R		P
4	H	4
2	O	2

This is the answer

Not this

21

Examples

$CH_4 + O_2 \rightarrow CO_2 + H_2O$

22

Examples

$AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + Ag$

23

Examples

$Al + N_2 \rightarrow Al_2N_3$

24

Examples

$P + O_2 \rightarrow P_4O_{10}$

25

Examples

$Na + H_2O \rightarrow H_2 + NaOH$

26

Techniques

- If an atom appears more than once on a side, balance it last.
- If you fix everything except one element, and it is even on one side and odd on the other, double the first number, then move on from there.
- $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$

27

Types of Reactions

Predicting the Products

28

Types of Reactions

- There are too many reactions to remember
- Fall into categories.
- We will learn 5 types.
- Will be able to predict the products.
- For some we will be able to predict whether they will happen at all.
- Must recognize them by the reactants

29

#1 Combination Reactions

- Combine - put together
- 2 elements, or compounds combine to make 1 compound.
- $Ca + O_2 \rightarrow CaO$
- $SO_3 + H_2O \rightarrow H_2SO_4$
- We can predict the products if they are two elements.
- $Mg + N_2 \rightarrow$

30

Write and balance

- **Ca + Cl_2 →**

31

Write and balance

- **Fe + O_2 → iron (II) oxide**

32

Write and balance

- **Al + O_2 →**
- **Remember that the first step is to write the formula**
- **Then balance**
- **Also called synthesis reaction**

33

Combining two compounds

- **If they tell you it is combination, you will make one product**
- **Two compounds will make a polyatomic ion.**
- **CO_2 + H_2O →**
- **H_2O + Cl_2O_7→**

34

#2 Decomposition Reactions

- **decompose = fall apart**
- **one reactant falls apart into two or more elements or compounds.**
- **NaCl Na + Cl_2**
- **$CaCO_3$ CaO + CO_2**

35

#2 Decomposition Reactions

- **Can predict the products if it is a binary compound**
- **Made up of only two elements**
- **Falls apart into its elements**
- **H_2O**

36

#2 Decomposition Reactions

- **HgO**

37

#2 Decomposition Reactions

- **If the compound has more than two elements you must be given one of the products**
- **The other product will be from the missing pieces**
- **$NiCO_3$ NiO +**
- **$H_2CO_3(aq) \rightarrow$ CO_2 +**

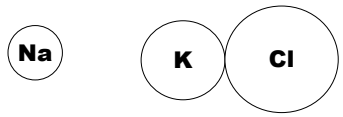
38

#3 Single Replacement

- **One element replaces another**
- **Reactants must be an element and a compound.**
- **Products will be a different element and a different compound.**
- **Na + KCl → K + NaCl**
- **F_2 + LiCl → LiF + Cl_2**

39

Na + KCl → K + NaCl



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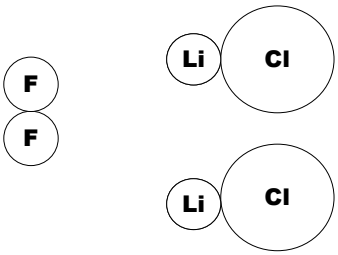
F_2 + 2 LiCl → 2 LiF + Cl_2



41

#3 Single Replacement

- **Metals replace metals (and hydrogen)**
- **Al + $CuSO_4$ →**
- **Zn + H_2SO_4 →**
- **Think of water as HOH**
- **Metals replace one of the H, combine with hydroxide.**
- **Na + HOH →**

42

#3 Single Replacement

- **We can tell whether a reaction will happen**
- **Some are more active than other**
- **More active replaces less active**
- **There is a list on page 333**

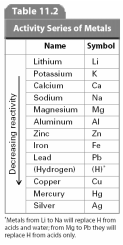


Table 11.2
Activity Series of Metals

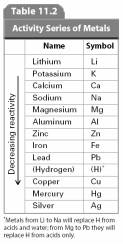
	Name	Symbol
Decreasing reactivity ↓	Lithium	Li
	Potassium	K
	Calcium	Ca
	Sodium	Na
	Magnesium	Mg
	Aluminum	Al
	Zinc	Zn
	Iron	Fe
	Lead	Pb
	(Hydrogen)	(H)*
	Copper	Cu
	Mercury	Hg
	Silver	Ag

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

43

#3 Single Replacement

- **There is a list on page 333**
- **Higher on the list replaces lower.**
- **If the element by itself is higher, it happens,**
- **if element by itself is lower, it doesn't**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	Iron	Fe
	Lead	Pb
	(Hydrogen)	(H)*
	Copper	Cu
	Mercury	Hg
	Silver	Ag

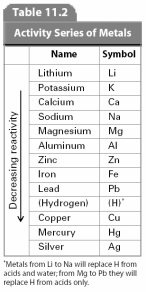
*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

44

#3 Single Replacement

- **Note the ***
- **H can be replaced in acids by everything higher**
- **Only the first 4 (Li - Na) react with water.**

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.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	Copper	Cu
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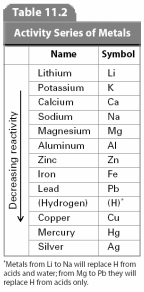
	Silver	Ag

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

45

#3 Single Replacement

- **Al + HCl →**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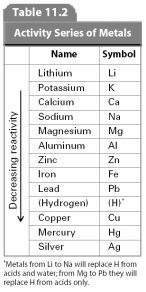
	Lead	Pb
	(Hydrogen)	(H)*
	Copper	Cu
	Mercury	Hg
	Silver	Ag

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

46

#3 Single Replacement

- **Fe + $CuSO_4$ →**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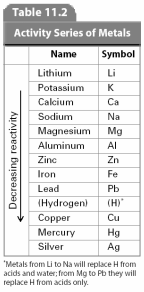
	Iron	Fe
	Lead	Pb
	(Hydrogen)	(H)*
	Copper	Cu
	Mercury	Hg
	Silver	Ag

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

47

#3 Single Replacement

- **Pb + KCl →**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	Zinc	Zn
	Iron	Fe
	Lead	Pb
	(Hydrogen)	(H)*
	Copper	Cu
	Mercury	Hg
	Silver	Ag

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

48

#3 Single Replacement

- $Al + H_2O \rightarrow$

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	Potassium	K
	Calcium	Ca
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	Magnesium	Mg
	Aluminum	Al
	Zinc	Zn
	Iron	Fe
	Lead	Pb
	(Hydrogen)	$(H)^*$
	Copper	Cu
	Mercury	Hg
	Silver	Ag

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

49

#3 Single Replacement

- What does it mean that Ag is on the bottom of the list?

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	Lead	Pb
	(Hydrogen)	$(H)^*$
	Copper	Cu
	Mercury	Hg
	Silver	Ag

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

50

#3 Single Replacement

- Nonmetals can replace other nonmetals
- Limited to F_2 , Cl_2 , Br_2 , I_2
- The order of activity is that on the table.
- Higher replaces lower.
- $F_2 + HCl \rightarrow$
- $Br_2 + KCl \rightarrow$

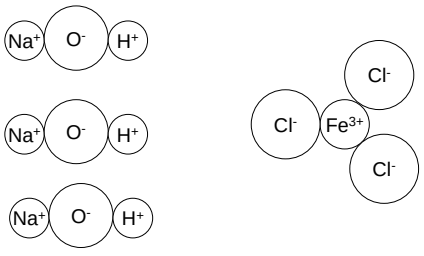
51

#4 Double Replacement

- Two things replace each other.
- Reactants must be two ionic compounds or acids.
- Usually in aqueous solution
- $NaOH + FeCl_3 \rightarrow$
- The positive ions change place.
- $NaOH + FeCl_3 \rightarrow Fe^{3+}OH^- + Na^+Cl^-$
- $NaOH + FeCl_3 \rightarrow Fe(OH)_3 + NaCl$

52

$3NaOH + FeCl_3 \rightarrow Fe(OH)_3 + 3NaCl$



53

#4 Double Replacement

- Will only happen if one of the products
  - doesn't dissolve in water and forms a solid
  - or is a gas that bubbles out.
  - or is a covalent compound usually water.
- Polyatomic ions don't change from side to side

54

Complete and balance

- assume all of the reactions take place.
- $CaCl_2 + NaOH \rightarrow$
- $CuCl_2 + K_2S \rightarrow$
- $KOH + Fe(NO_3)_3 \rightarrow$

55

Complete and balance

- $KOH + Fe(NO_3)_3 \rightarrow$
- $H_3PO_4 + Ca(OH)_2 \rightarrow$

56

How to recognize which type

- Look at the reactants
- E for element
- C for compound
- E + E Combination
- C Decomposition
- E + C Single replacement
- C + C Double replacement

57

Last Type

- Combustion
- A compound composed of only C H and maybe O is reacted with oxygen
- If the combustion is complete, the products will be CO_2 and H_2O.
- If the combustion is incomplete, the products will be CO and H_2O.
- or just C and H_2O.
- O_2 will always be the second reactant

58

Examples

- Complete combustion of C_4H_{10}
- Incomplete combustion of C_4H_{10}

59

Examples

- Complete combustion of $C_6H_{12}O_6$
- Incomplete combustion of C_2H_6O

60

Ionic Compounds and acids

- Fall apart into ions when they dissolve
- That's why they conduct electricity when dissolved.
- So when we write them as (aq) they are really separated
- NaCl(aq) is really $Na^+(aq)$ and $Cl^-(aq)$
- K_2SO_4 (aq) is really $K^+(aq)$ and $SO_4^{2-}(aq)$

61

Reactions in aqueous solutions

- Many reactions happen in solution
- Makes it so the ions separate so they can interact.
- Solids, liquids, and gases are not separated, only aqueous

62

Complete Ionic Equation

- Every aqueous compound is written as separate ions
- Solids, liquids and gases as whole compounds
- $MgCl_2(aq) + PbSO_4(aq) \rightarrow MgSO_4(aq) + PbCl_2(s)$
- Is really
- $Mg^{2+}(aq) + Cl^-(aq) + Pb^{2+}(aq) + SO_4(aq) \rightarrow Mg^{2+}(aq) + SO_4(aq) + PbCl_2(s)$

63

Write the complete ionic equation for

- $FeBr_3(aq) + KOH(aq) \rightarrow KBr(aq) + Fe(OH)_3(s)$

+ + + →

+ +

64

Write the complete ionic equation for

- $CaCl_2(aq) + MgSO_4(aq) \rightarrow CaSO_4(s) + MgCl_2(aq)$

65

Write the complete ionic equation for

- $Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + HOH(l)$

66

The complete ionic equation is

- $Fe^{3+}(aq) + Br^{-}(aq) + K^{+}(aq) + OH^{-}(aq) \rightarrow K^{+}(aq) + Br^{-}(aq) + Fe(OH)_3(s)$
- K^+ and Br^- don't change.
- They are spectator ions
- Could be eliminated
- $Fe^{3+}(aq) + OH^{-}(aq) \rightarrow Fe(OH)_3(s)$
- This is what really changes

67

Net ionic equation

- Shows only those particles that change before and after.
- Eliminate spectator ions
- Needs to be balanced in terms of both mass and charge
- $Fe^{3+}(aq) + OH^{-}(aq) \rightarrow Fe(OH)_3(s)$
- $Fe^{3+}(aq) + 3\ OH^{-}(aq) \rightarrow Fe(OH)_3(s)$

68

Write the net ionic equation

- $HCl\ (aq) + Ba(OH)_2\ (aq) \rightarrow BaCl_2(s) + HOH\ (l)$

69

Write the net ionic equation

- $Al + FeSO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + Fe$

70

Write the net ionic equation

- $Cl_2(s) + NaI(aq) \rightarrow NaCl(aq) + I_2(s)$

71

Write the net ionic equation

- $K_2CO_3(aq) + MgI_2(aq) \rightarrow MgCO_3(s) + KI(aq)$

72

Net ionic equations

- **Written for single and double replacement.**

73

Predicting precipitates

- **Solids formed from aqueous solution.**
- **You can predict them if you know some general rules for solubility.**

74

These things are soluble

1. **Salts with alkali metals and ammonium**
2. **Salts of nitrates and chlorates**
3. **Salts of sulfates except Ag^+, Pb^{2+}, Hg_2^{2+}, Ba^{2+}, and Sr^{2+}**
4. **Salts of chlorides except Ag^+, Pb^{2+}, and Hg_2^{2+}**

75

These things are insoluble

5. **Carbonates, phosphates, chromates, sulfides, and hydroxides**
- **Unless they fall under rule # 1**

76

Is it soluble?

- **LiBr**
- **$Ba(NO_3)_2$**
- **$CaSO_4$**
- **$PbCl_2$**
- **$CaCO_3$**
- **K_2CO_3**
- **$Cd(ClO_3)_2$**

77

Is there a reaction?

- **For double replacement- has to make gas, solid or water.**
- **Water from an acid- H^+ and a hydroxide- OH^- makes HOH**
- **Solids- from solubility rules**
- **Exchange ions and see if something is insoluble**

78

Is there a reaction?

- $MgSO_4 + NaOH \rightarrow$
- $H_2SO_4 + KOH \rightarrow$
- $K_3PO_4 + FeF_3 \rightarrow$

79

Chapter 7 Summary

80

An equation

- Describes a reaction
- Must be balanced to follow the Law of Conservation of Mass
- Can only be balanced by changing the coefficients.
- Has special symbols to indicate state, and if catalyst or energy is required.

81

Reactions

- Come in 5 types.
- Can tell what type they are by the reactants.
- Single Replacement happens based on the activity series
- Double Replacement happens if the product is a solid, water, or a gas.

82

The Process

1. Determine the type by looking at the reactants.
2. Put the pieces next to each other based on type
3. Use charges to write the formulas
   - Elements get 2?
4. Use coefficients to balance the equation.

83