# APPLYING THE SOLUBILITY RULES FOR IONIC COMPOUNDS
# &
# NET IONIC EQUATIONS

1. Write net ionic equations for the reactions (if any) which occur when solutions of the following pairs of substances are mixed. If there is no reaction write **no rxn**.

   a. sodium chloride & silver nitrate
   b. barium chloride & sodium sulphate
   c. copper sulphate & potassium hydroxide
   d. nickel chloride & potassium sulphate
   e. sodium carbonate & iron(II) sulphate
   f. zinc nitrate & ammonium sulphide
   g. ammonium bromide & lead nitrate
   h. potassium carbonate & calcium chloride
   i. iron(II) sulphate & potassium iodide
   j. silver nitrate & sulphuric acid
   k. potassium sulphate & magnesium chloride
   l. nickel chloride & sodium hydroxide
   m. copper nitrate & hydrogen sulphide

2. Solutions of what substances would you mix in order to prepare the following compounds by precipitation? Write net ionic equations for your reactions.

   a. magnesium carbonate
   b. magnesium hydroxide
   c. lead sulphate
   d. iron(II) sulphide
   e. silver bromide
   f. lead iodide

3. What cations (+ve ions) could be present in a solution which gave a precipitate with

   a. sodium sulphate solution but not with sodium chloride?
   b. sodium sulphate solution and with sodium chloride?
   c. sodium sulphate solution but not with sodium hydroxide?
   d. sodium carbonate solution but not with sodium hydroxide?
   e. potassium hydroxide but not with ammonium sulphate?

4. Predict whether a reaction occurs when solutions of the following are added together and write balanced net ionic equations.

   a. iron(III) chloride & caesium phosphate
   b. potassium hydroxide & lead nitrate
   c. magnesium iodide & sodium sulphate
   d. silver nitrate & barium chloride

5. Use the solubility rules to predict which of the following combinations lead to reaction.

   a. calcium nitrate & potassium chloride
   b. sodium chloride & lead(II) nitrate

6. For each of the following pairs of aqueous solutions state whether a precipitation reaction occurs when they are mixed. Write the formulae and names of any precipitates that form.

a. sodium nitrate & copper(II) sulphate
b. ammonium iodide & silver nitrate
c. potassium carbonate & barium hydroxide
d. aluminium nitrate & sodium phosphate
e. potassium chloride & iron(II) nitrate
f. ammonium sulphate & barium chloride
g. sodium sulphide & nickel(II) sulphate
h. lead(II) nitrate & potassium bromide

7. Complete the following precipitation reactions with balanced net ionic equations and identify the spectator ions.

a. $FeSO_{4(aq)}$ & $Ba(OH)_{2(aq)}$
b. $CaCl_{2(aq)}$ & $Cs_3PO_{4(aq)}$
c. $Na_2S_{(aq)}$ & $ZnSO_{4(aq)}$
d. $KOH_{(aq)}$ & $Ca(NO_3)_2$
e. $Na_2S_{(aq)}$ & $Pb(CH_3COO)_{2(aq)}$
f. $(NH_4)_3PO_{4(aq)}$ & $CaCl_{2(aq)}$

8. Use the solubility rules to predict whether each of the following ionic compounds is soluble in water.

a. $BaSO_4$ b. $Pb(NO_3)_2$ c. $PbI_2$ d. $Na_2S$

9. The following combinations of aqueous solutions are mixed. In each case
i predict whether a precipitate will form
ii if a precipitate does form, write a balanced net ionic equation for its formation and give its correct chemical name

a. ammonium hydroxide & copper(II) nitrate
b. sodium carbonate & calcium chloride
c. barium chloride & potassium hydroxide
d. ammonium sulphate & sodium chloride
e. potassium hydroxide & calcium nitrate
f. silver nitrate & potassium iodide
g. sodium hydroxide & copper(II) nitrate
h. copper(II) sulphate & sodium chloride
i. potassium sulphate & barium nitrate

10. Use the solubility rules to determine which

a. sodium compounds are soluble in water
b. potassium compounds are insoluble
c. silver compounds are soluble

11. Predict products and write balanced net ionic equations for

a. $KOH_{(aq)} + Ca(NO_3)_{2(aq)} \rightarrow$
b. $Na_2S_{(aq)} + Pb(CH_3COO)_{2(aq)} \rightarrow$
c. $(NH_4)_3PO_{4(aq)} + CaCl_{2(aq)} \rightarrow$

12. A WACE Chemistry student was testing the solubility of a number of ionic compounds by mixing solutions and observing whether or not a precipitate formed. The solutions to be mixed were:

a. $CuCl_{2(aq)}$ & $K_2CO_{3(aq)}$
b. $Pb(NO_3)_2$ & $CuSO_{4(aq)}$
c. $NH_4Br_{(aq)}$ & $NaOH_{(aq)}$

Before mixing the solutions the student tried to predict the results that would be obtained using their knowledge of the solubility rules for ionic compounds located on the WACE Chemistry Data Sheet. For each of the mixtures a to c:

i. Indicate whether a precipitate would form.
ii. Write a balanced net ionic equation for any precipitate that you think would form.

13. "Milk of Magnesia" is a treatment for indigestion. Chemically it is magnesium hydroxide, $Mg(OH)_2$. The instructions on a bottle of milk of magnesia say that the bottle should be well shaken before it is taken. Why is this instruction given?

14. Write dissociation equations for

a. $NaOH_{(s)}$ b. $Na_3PO_{4(s)}$
c. $NH_4Cl_{(s)}$ d. $AlCl_{3(s)}$

15. Write net ionic equations for the following aqueous reactions

a. barium chloride & magnesium sulphate
b. calcium nitrate & sodium carbonate
c. potassium hydroxide & calcium nitrate
d. sodium sulphide & lead ethanoate
e. ammonium phosphate & calcium chloride

16. Which of the following compounds would appear as a precipitate in solution?

a. ammonium sulphate b. barium nitrate
c. barium sulphate d. ammonium hydroxide

17. Which of the following is **NOT** a correctly balanced net ionic equation?

a. $Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$
b. $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightarrow SO_4^{2-}_{(aq)} + H_3O^+_{(aq)}$
c. $2H^+_{(aq)} + SO_4^-{}_{(aq)} + 2K^+_{(aq)} + 2OH^-_{(aq)} \rightarrow SO_4^{2-}_{(aq)} + 2K^+_{(aq)} + 2H_2O_{(l)}$
d. $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

18. In which of the following instances does a chemical reaction **NOT** occur?

a. Solutions of ammonium chloride & potassium nitrate are mixed
b. Solutions of magnesium bromide & sodium hydroxide are mixed
b. Solutions of hydrochloric acid & silver nitrate are mixed
c. Solutions of barium hydroxide & sulphuric acid are mixed

Write net ionic equations for the reactions which do occur in 18. above.

19. Rewrite and complete the following equations as balanced net ionic equations.

| | | | | |
|---|---|---|---|---|
| a. | $Ca(OH)_{2(s)}$ | + | $H_3PO_{4(aq)}$ | → |
| b. | $H_2SO_{4(aq)}$ | + | $Al(OH)_{3(s)}$ | → |
| c. | $Fe(OH)_{3(s)}$ | + | $HCl_{(aq)}$ | → |
| d. | $BaCl_{2(aq)}$ | + | $(NH_4)_2CO_{3(aq)}$ | → |
| e. | $AgNO_{3(aq)}$ | + | $H_2S_{(g)}$ | → |
| f. | $K_2CrO_{4(aq)}$ | + | $Pb(NO_3)_{2(aq)}$ | → |

20. Write a balanced net ionic equation, showing the physical states of reactants and products, for each of the following aqueous reactions.

| | | | | |
|---|---|---|---|---|
| a. | silver nitrate | & | calcium chloride | → |
| b. | aluminium nitrate | & | sodium hydroxide | → |
| c. | barium chloride | & | potassium phosphate | → |

21. Hard water can be caused by the presence of calcium ions (in calcium chloride or calcium hydrogen carbonate). Hard water reacts with soap forming a precipitate, soap may be represented by the formula $NaOOC(CH_2)_{14}CH_3$. These calcium ions can be removed by adding sodium carbonate (washing soda) solution to the hard water.

a. Write a net ionic equation for the reaction of hard water with soap.
b. Write a net ionic equation for the reaction of hard water with sodium carbonate.

22. A precipitation reaction produces zinc phosphate as one of its products.

a. Suggest two reactants that may have participated in this reaction.
b. Write a balanced net ionic equation for this reaction.

23. Identify the substances from the following list which are soluble in water.

| | | | | | |
|---|---|---|---|---|---|
| a. | $CaI_2$ | b. | $KOH$ | c. | $AgCl$ |
| d. | $BaSO_4$ | e. | $AgI$ | f. | $NH_4Cl$ |
| g. | $Na_2S$ | h. | $MgCl_2$ | i. | $CuS$ |
| j. | $Al(OH)_3$ | k. | $PbI_2$ | l. | $Fe(OH)_3$ |

24. Predict whether a precipitate will form when solutions of the following are mixed:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a. | $AgNO_3$ | & | $KCl$ | b. | $H_2SO_4$ | & | $BaCl_2$ |
| c. | $H_2SO_4$ | & | $NaCl$ | d. | $NaNO_3$ | & | $KCl$ |
| e. | $(NH_4)_3PO_4$ | & | $CaCl_2$ | f. | $(NH_4)_2S$ | & | $Pb(NO_3)_2$ |
| g. | $(NH_4)_2S$ | & | $NaNO_3$ | h. | $CaCl_2$ | & | $NaBr$ |

25. Write net ionic equations for the reactions which did occur in 25. above.

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ANSWERS:

1. a. $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$
   b. $Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$
   c. $Cu^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Cu(OH)_{2(s)}$
   d. no rxn
   e. $Fe^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow FeCO_{3(s)}$
   f. $Zn^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow ZnS_{(s)}$
   g. $Pb^{2+}_{(aq)} + 2I^{-}_{(aq)} \rightarrow PbI_{2(s)}$
   h. $Ca^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CaCO_{3(s)}$
   i. no rxn
   j. $2Ag^{+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow Ag_2SO_{4(s)}$
   k. no rxn
   l. $Ni^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Ni(OH)_{2(s)}$
   m. $Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow CuS_{(s)}$

2. a. magnesium nitrate & sodium carbonate
   b. magnesium nitrate & sodium hydroxide
   c. lead nitrate & sodium sulfate
   d. iron(II) nitrate & sodium sulfide
   e. silver nitrate & sodium bromide
   f. lead nitrate & sodium iodide

3. a. $Sr^{2+}_{(aq)}$, $Ba^{2+}_{(aq)}$, $Ca^{2+}_{(aq)}$
   b. $Ag^{+}_{(aq)}$, $Pb^{2+}_{(aq)}$, $Sr^{2+}_{(aq)}$, $Ba^{2+}_{(aq)}$, $Ca^{2+}_{(aq)}$
   c. $Ba^{2+}_{(aq)}$
   e. $Ca^{2+}_{(aq)}$

4. a. $Fe^{3+}_{(aq)} + PO_4^{3-}_{(aq)} \rightarrow FePO_{4(s)}$
   b. $Pb^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Pb(OH)_{2(s)}$
   c. no rxn
   d. $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$

2. a. no rxn
   b. $Pb^{2+}_{(aq)} + 2Cl^{-}_{(aq)} \rightarrow PbCl_{2(s)}$

6. a. no rxn
   b. yes $AgI_{(s)}$
   c. yes $BaCO_{3(s)}$
   d. yes $Al_2(SO_4)_{3(s)}$
   e. no rxn
   f. yes $BaSO_{4(s)}$
   g. yes $NiS_{(s)}$
   i. yes $PbBr_{2(s)}$

7. a. $Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$ spectator ions: $Fe^{2+}_{(aq)}$ & $OH^{-}_{(aq)}$
   b. $3Ca^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$ spectator ions: $Cs^{+}_{(aq)}$ & $Cl^{-}_{(aq)}$
   c. $Zn^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow ZnS_{(s)}$ spectator ions: $Na^{+}_{(aq)}$ & $SO_4^{2-}_{(aq)}$
   d. $Ca^{2+}_{(aq)} + 2OH^{-}_{(aq)} = Ca(OH)_{2(s)}$ spectator ions: $K^{+}_{(aq)}$ & $NO_3^{-}_{(aq)}$
   e. $Pb^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)}$ spectator ions: $Na^{+}_{(aq)}$ & $CH_3COO^{-}_{(aq)}$
   f. $3Ca^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$ spectator ions: $NH_4^{+}_{(aq)}$ & $Cl^{-}_{(aq)}$

8. a. no
   b. yes
   c. no.
   d. yes

9. a. yes $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(OH)_{2(s)}$
b. yes $Ca^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CaCO_{3(s)}$
c. no rxn
d. no rxn
e. yes $Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$
f. yes $Ag^+_{(aq)} + I^-_{(aq)} \rightarrow AgI_{(s)}$
g. yes $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(OH)_{2(s)}$
h. no rxn
i. yes $Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$

10. a. all soluble no exceptions
b. none insoluble
c. all insoluble except silver nitrte ($AgNO_3$) and silver ethanoate ($CH_3COOAg$)

11. a. calcium hydroxide $Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$
b. lead sulfide $Pb^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)}$
c. calcium phosphate $3Ca^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$

12. a. yes $Cu^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CuCO_{3(s)}$
a. yes $Pb^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow PbSO_{4(s)}$
c. no rxn

13. Magnesium hydroxide is insoluble in water. The shaking is so the insoluble solid gets suspended in the solu

14. a. $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$
b. $Na_3PO_{4(s)} \rightarrow 3Na^+_{(aq)} + PO_4^{3-}_{(aq)}$
c. $NH_4Cl_{(s)} \rightarrow NH_4^+_{(aq)} + Cl^-_{(aq)}$
d. $AlCl_{3(s)} \rightarrow Al^{3+}_{(aq)} + 3Cl^-_{(aq)}$

15. a. $Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$
b. $Ca^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CaCO_{3(s)}$
c. $Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$
d. $Pb^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow PbS_{(s)}$
e. $3Ca^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$

16. c. $BaSO_{4(s)}$

17. c.

18. a. no rxn
b. $Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$
c. $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$
d. $Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$

19. a. $3Ca(OH)_{2(s)} + 6H^+_{(aq)} + 2PO_4^{3-}_{(aq} \rightarrow Ca_3(PO_4)_{2(s)} + 6H_2O_{(l)}$
b. $2Al(OH)_{3(s)} + 6H^+_{(aq))} \rightarrow 2Al^{3+}_{(s)} + 6H_2O_{(l)}$
c. $2Fe(OH)_{3(s)} + 6H^+_{(aq))} \rightarrow 2Fe^{3+}_{(s)} + 6H_2O_{(l)}$
d. $Ba^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CaCO_{3(s)}$
e. $2Ag^+_{(aq)} + S^{2-}_{(aq)} \rightarrow Ag_2S_{(s)}$
f. $Pb^{2+}_{(aq)} + CrO_4^{2-}_{(aq)} \rightarrow PbCrO_{4(s)}$

20. a. $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$
b. $Al^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Al(OH)_{3(s)}$
c. $3Ba^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)} \rightarrow Ba_3(PO_4)_{2(s)}$

21. a. $Ca^{2+}_{(aq)} + 2\,CH_3(CH_2)_{14}COO^-_{(aq)} \rightarrow Ca(CH_3(CH_2)_{14}COO)_{2(s)}$
b. $Ca^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightarrow CaCO_{3(s)}$

22. a. zinc nitrate & sodium phosphate
a. $3Zn^{2+}_{(aq)} + 2PO_4^{3-}_{(aq)} \rightarrow Zn_3(PO_4)_{2(s)}$

23.

a. soluble
b. soluble
c. insoluble
d. insoluble
e. insoluble
f. soluble
g. soluble
h. soluble
i. insoluble
j. insoluble
k. insoluble
l. insoluble

24. & 25.

| | | | | | |
|---|---|---|---|---|---|
| a. | yes | $Ag^{+}_{(aq)}$ + | $Cl^{-}_{(aq)}$ | $\rightarrow$ | $AgCl_{(s)}$ |
| b. | yes | $Ba^{2+}_{(aq)}$ + | $SO_4^{2-}{}_{(aq)}$ | $\rightarrow$ | $BaSO_{4(s)}$ |
| c. | no rxn | | | | |
| d. | no rxn | | | | |
| e. | yes | $3Ca^{2+}_{(aq)}$+ | $2PO_4^{3-}{}_{(aq)}$ | $\rightarrow$ | $Ca_3(PO_4)_{2(s)}$ |
| f. | yes | $Pb^{2+}_{(aq)}$ + | $S^{2-}_{(aq)}$ | $\rightarrow$ | $PbS_{(s)}$ |
| g. | no rxn | | | | |
| h. | no rxn | | | | |