

# Solubility Rules

Simulation: [edtechsims.com/solubility-rules](https://edtechsims.com/solubility-rules)

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_



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## Part A: Deduce the Solubility Rules

Table 1 shows whether 30 salts are soluble (S) or insoluble (I) in water. Study the data to work out the solubility rules.

| Salt                 | Formula                           | S / I | Salt                | Formula                                         | S / I |
|----------------------|-----------------------------------|-------|---------------------|-------------------------------------------------|-------|
| Silver chloride      | AgCl                              | I     | Calcium sulfate     | CaSO <sub>4</sub>                               | I     |
| Sodium carbonate     | Na <sub>2</sub> CO <sub>3</sub>   | S     | Magnesium chloride  | MgCl <sub>2</sub>                               | S     |
| Copper(II) sulfate   | CuSO <sub>4</sub>                 | S     | Zinc carbonate      | ZnCO <sub>3</sub>                               | I     |
| Calcium carbonate    | CaCO <sub>3</sub>                 | I     | Copper(II) nitrate  | Cu(NO <sub>3</sub> ) <sub>2</sub>               | S     |
| Lead(II) nitrate     | Pb(NO <sub>3</sub> ) <sub>2</sub> | S     | Copper(II) oxide    | CuO                                             | I     |
| Magnesium oxide      | MgO                               | I     | Ammonium carbonate  | (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub> | S     |
| Ammonium chloride    | NH <sub>4</sub> Cl                | S     | Lead(II) sulfate    | PbSO <sub>4</sub>                               | I     |
| Barium sulfate       | BaSO <sub>4</sub>                 | I     | Sodium chloride     | NaCl                                            | S     |
| Zinc chloride        | ZnCl <sub>2</sub>                 | S     | Magnesium hydroxide | Mg(OH) <sub>2</sub>                             | I     |
| Iron(III) hydroxide  | Fe(OH) <sub>3</sub>               | I     | Zinc sulfate        | ZnSO <sub>4</sub>                               | S     |
| Potassium sulfate    | K <sub>2</sub> SO <sub>4</sub>    | S     | Calcium nitrate     | Ca(NO <sub>3</sub> ) <sub>2</sub>               | S     |
| Copper(II) carbonate | CuCO <sub>3</sub>                 | I     | Potassium carbonate | K <sub>2</sub> CO <sub>3</sub>                  | S     |
| Silver nitrate       | AgNO <sub>3</sub>                 | S     | Copper(II) chloride | CuCl <sub>2</sub>                               | S     |
| Lead(II) chloride    | PbCl <sub>2</sub>                 | I     | Magnesium sulfate   | MgSO <sub>4</sub>                               | S     |
| Sodium hydroxide     | NaOH                              | S     | Sodium nitrate      | NaNO <sub>3</sub>                               | S     |

Table 1

**A1** Use Table 1 to complete Table 2. Write the formulae of the salts in each group.

[6]

| Group                                | Soluble salts | Insoluble salts |
|--------------------------------------|---------------|-----------------|
| Sodium, potassium and ammonium salts |               |                 |
| Nitrates                             |               |                 |
| Chlorides                            |               |                 |
| Sulfates                             |               |                 |
| Carbonates                           |               |                 |
| Oxides and hydroxides                |               |                 |

*Table 2*

**A2** Use Table 2 to complete the solubility rules. These are the four rules used in the game. [10]

1. All \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_ salts are soluble. (The first letters spell \_\_\_\_\_)
2. Most chlorides are soluble, except \_\_\_\_\_ chloride and \_\_\_\_\_ chloride.
3. Most sulfates are soluble, except \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_ sulfates.
4. Most carbonates, oxides and hydroxides are \_\_\_\_\_, except those of \_\_\_\_\_, potassium and ammonium.

## Part B: Sort the Salts

**On the sim:** Before you play the game, predict whether each salt is soluble or insoluble, and state the rule you used. Then check your predictions in the game.

**B1** Complete Table 3.

[14]

| Salt               | Formula                      | S / I | Rule used |
|--------------------|------------------------------|-------|-----------|
| Potassium nitrate  | $\text{KNO}_3$               |       |           |
| Lead(II) carbonate | $\text{PbCO}_3$              |       |           |
| Barium chloride    | $\text{BaCl}_2$              |       |           |
| Aluminium oxide    | $\text{Al}_2\text{O}_3$      |       |           |
| Ammonium sulfate   | $(\text{NH}_4)_2\text{SO}_4$ |       |           |
| Iron(II) sulfate   | $\text{FeSO}_4$              |       |           |
| Lead(II) hydroxide | $\text{Pb}(\text{OH})_2$     |       |           |
| Barium nitrate     | $\text{Ba}(\text{NO}_3)_2$   |       |           |
| Zinc oxide         | $\text{ZnO}$                 |       |           |
| Sodium phosphate   | $\text{Na}_3\text{PO}_4$     |       |           |
| Iron(II) hydroxide | $\text{Fe}(\text{OH})_2$     |       |           |
| Barium carbonate   | $\text{BaCO}_3$              |       |           |
| Ammonium nitrate   | $\text{NH}_4\text{NO}_3$     |       |           |
| Calcium chloride   | $\text{CaCl}_2$              |       |           |

Table 3

## Part C: Game Record

**On the sim:** Play the game three times. Use Show Solubility Rules only if you need to.

| Attempt | Score | Time | Salts I got wrong |
|---------|-------|------|-------------------|
| 1       |       |      |                   |
| 2       |       |      |                   |
| 3       |       |      |                   |

**C1** Choose one salt you got wrong. Which rule should you have used?

[1]

## Part D: Applying the Rules

**D1** The method used to prepare a salt depends on its solubility. Complete Table 4. [6]

| Salt to prepare    | S / I | Method (precipitation, titration or excess solid + acid) |
|--------------------|-------|----------------------------------------------------------|
| Barium sulfate     |       |                                                          |
| Sodium chloride    |       |                                                          |
| Copper(II) sulfate |       |                                                          |
| Lead(II) chloride  |       |                                                          |
| Zinc sulfate       |       |                                                          |
| Potassium nitrate  |       |                                                          |

Table 4

**D2** Two solutions are mixed. State whether a precipitate forms. If it does, name it. [4]

| Solutions mixed                       | Precipitate formed |
|---------------------------------------|--------------------|
| Silver nitrate + sodium chloride      |                    |
| Barium chloride + potassium sulfate   |                    |
| Sodium nitrate + potassium chloride   |                    |
| Copper(II) sulfate + sodium hydroxide |                    |

## Part E: Practice Questions

**E1** Lead(II) nitrate solution is added to dilute sulfuric acid.

(a) Name the precipitate formed. [1]

.....

(b) Write the ionic equation, with state symbols, for the formation of the precipitate. [2]

.....

**E2** Describe how you would prepare a pure, dry sample of lead(II) sulfate from lead(II) nitrate solution.

[4]

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**E3** Explain why lead(II) carbonate cannot be made by reacting a lead compound with an acid, and state the method that should be used.

[2]

.....

.....

.....

## Answer Key: Solubility Rules

### Part A: Deduce the Solubility Rules

Table 1 shows whether 30 salts are soluble (S) or insoluble (I) in water. Study the data to work out the solubility rules.

| Salt                 | Formula                           | S / I | Salt                | Formula                                         | S / I |
|----------------------|-----------------------------------|-------|---------------------|-------------------------------------------------|-------|
| Silver chloride      | AgCl                              | I     | Calcium sulfate     | CaSO <sub>4</sub>                               | I     |
| Sodium carbonate     | Na <sub>2</sub> CO <sub>3</sub>   | S     | Magnesium chloride  | MgCl <sub>2</sub>                               | S     |
| Copper(II) sulfate   | CuSO <sub>4</sub>                 | S     | Zinc carbonate      | ZnCO <sub>3</sub>                               | I     |
| Calcium carbonate    | CaCO <sub>3</sub>                 | I     | Copper(II) nitrate  | Cu(NO <sub>3</sub> ) <sub>2</sub>               | S     |
| Lead(II) nitrate     | Pb(NO <sub>3</sub> ) <sub>2</sub> | S     | Copper(II) oxide    | CuO                                             | I     |
| Magnesium oxide      | MgO                               | I     | Ammonium carbonate  | (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub> | S     |
| Ammonium chloride    | NH <sub>4</sub> Cl                | S     | Lead(II) sulfate    | PbSO <sub>4</sub>                               | I     |
| Barium sulfate       | BaSO <sub>4</sub>                 | I     | Sodium chloride     | NaCl                                            | S     |
| Zinc chloride        | ZnCl <sub>2</sub>                 | S     | Magnesium hydroxide | Mg(OH) <sub>2</sub>                             | I     |
| Iron(III) hydroxide  | Fe(OH) <sub>3</sub>               | I     | Zinc sulfate        | ZnSO <sub>4</sub>                               | S     |
| Potassium sulfate    | K <sub>2</sub> SO <sub>4</sub>    | S     | Calcium nitrate     | Ca(NO <sub>3</sub> ) <sub>2</sub>               | S     |
| Copper(II) carbonate | CuCO <sub>3</sub>                 | I     | Potassium carbonate | K <sub>2</sub> CO <sub>3</sub>                  | S     |
| Silver nitrate       | AgNO <sub>3</sub>                 | S     | Copper(II) chloride | CuCl <sub>2</sub>                               | S     |
| Lead(II) chloride    | PbCl <sub>2</sub>                 | I     | Magnesium sulfate   | MgSO <sub>4</sub>                               | S     |
| Sodium hydroxide     | NaOH                              | S     | Sodium nitrate      | NaNO <sub>3</sub>                               | S     |

Table 1

**A1** Use Table 1 to complete Table 2. Write the formulae of the salts in each group.

[6]

| Group                                | Soluble salts                                                                                                                                                                                           | Insoluble salts                                           |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| Sodium, potassium and ammonium salts | Na <sub>2</sub> CO <sub>3</sub> , NH <sub>4</sub> Cl, K <sub>2</sub> SO <sub>4</sub> , NaOH, (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub> , NaCl, K <sub>2</sub> CO <sub>3</sub> , NaNO <sub>3</sub> | none                                                      |
| Nitrates                             | Pb(NO <sub>3</sub> ) <sub>2</sub> , AgNO <sub>3</sub> , Cu(NO <sub>3</sub> ) <sub>2</sub> , Ca(NO <sub>3</sub> ) <sub>2</sub> , NaNO <sub>3</sub>                                                       | none                                                      |
| Chlorides                            | ZnCl <sub>2</sub> , NH <sub>4</sub> Cl, MgCl <sub>2</sub> , NaCl, CuCl <sub>2</sub>                                                                                                                     | AgCl, PbCl <sub>2</sub>                                   |
| Sulfates                             | CuSO <sub>4</sub> , K <sub>2</sub> SO <sub>4</sub> , ZnSO <sub>4</sub> , MgSO <sub>4</sub>                                                                                                              | BaSO <sub>4</sub> , CaSO <sub>4</sub> , PbSO <sub>4</sub> |
| Carbonates                           | Na <sub>2</sub> CO <sub>3</sub> , (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub>                                                                                      | CaCO <sub>3</sub> , CuCO <sub>3</sub> , ZnCO <sub>3</sub> |
| Oxides and hydroxides                | NaOH                                                                                                                                                                                                    | MgO, Fe(OH) <sub>3</sub> , CuO, Mg(OH) <sub>2</sub>       |

Table 2

**A2** Use Table 2 to complete the solubility rules. These are the four rules used in the game. [10]

1. All **sodium**, **potassium**, **ammonium** and **nitrate** salts are soluble. (The first letters spell **S.P.A.N.**)
2. Most chlorides are soluble, except **lead(II)** chloride and **silver** chloride.
3. Most sulfates are soluble, except **lead(II)**, **calcium** and **barium** sulfates.
4. Most carbonates, oxides and hydroxides are **insoluble**, except those of **sodium**, potassium and ammonium.

## Part B: Sort the Salts

**On the sim:** Before you play the game, predict whether each salt is soluble or insoluble, and state the rule you used. Then check your predictions in the game.

**B1** Complete Table 3.

[14]

| Salt               | Formula                      | S / I | Rule used          |
|--------------------|------------------------------|-------|--------------------|
| Potassium nitrate  | $\text{KNO}_3$               | S     | S.P.A.N.           |
| Lead(II) carbonate | $\text{PbCO}_3$              | I     | Carbonates         |
| Barium chloride    | $\text{BaCl}_2$              | S     | Chlorides          |
| Aluminium oxide    | $\text{Al}_2\text{O}_3$      | I     | Oxides             |
| Ammonium sulfate   | $(\text{NH}_4)_2\text{SO}_4$ | S     | S.P.A.N.           |
| Iron(II) sulfate   | $\text{FeSO}_4$              | S     | Sulfates           |
| Lead(II) hydroxide | $\text{Pb}(\text{OH})_2$     | I     | Hydroxides         |
| Barium nitrate     | $\text{Ba}(\text{NO}_3)_2$   | S     | S.P.A.N. (nitrate) |
| Zinc oxide         | $\text{ZnO}$                 | I     | Oxides             |
| Sodium phosphate   | $\text{Na}_3\text{PO}_4$     | S     | S.P.A.N.           |
| Iron(II) hydroxide | $\text{Fe}(\text{OH})_2$     | I     | Hydroxides         |
| Barium carbonate   | $\text{BaCO}_3$              | I     | Carbonates         |
| Ammonium nitrate   | $\text{NH}_4\text{NO}_3$     | S     | S.P.A.N.           |
| Calcium chloride   | $\text{CaCl}_2$              | S     | Chlorides          |

Table 3

## Part C: Game Record

**On the sim:** Play the game three times. Use Show Solubility Rules only if you need to.

| Attempt | Score | Time | Salts I got wrong |
|---------|-------|------|-------------------|
| 1       |       |      |                   |
| 2       |       |      |                   |
| 3       |       |      |                   |

- C1** Choose one salt you got wrong. Which rule should you have used? [1]  
Open response; the rule must match the salt.

## Part D: Applying the Rules

- D1** The method used to prepare a salt depends on its solubility. Complete Table 4. [6]

| Salt to prepare    | S / I | Method (precipitation, titration or excess solid + acid)                                 |
|--------------------|-------|------------------------------------------------------------------------------------------|
| Barium sulfate     | I     | Precipitation (e.g. $\text{BaCl}_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq})$ )     |
| Sodium chloride    | S     | Titration ( $\text{NaOH}(\text{aq}) + \text{HCl}(\text{aq})$ )                           |
| Copper(II) sulfate | S     | Excess solid ( $\text{CuO}$ or $\text{CuCO}_3$ ) + $\text{H}_2\text{SO}_4$               |
| Lead(II) chloride  | I     | Precipitation (e.g. $\text{Pb}(\text{NO}_3)_2(\text{aq}) + \text{NaCl}(\text{aq})$ )     |
| Zinc sulfate       | S     | Excess solid ( $\text{Zn}$ , $\text{ZnO}$ or $\text{ZnCO}_3$ ) + $\text{H}_2\text{SO}_4$ |
| Potassium nitrate  | S     | Titration ( $\text{KOH}(\text{aq}) + \text{HNO}_3(\text{aq})$ )                          |

Table 4

- D2** Two solutions are mixed. State whether a precipitate forms. If it does, name it. [4]

| Solutions mixed                       | Precipitate formed                                                         |
|---------------------------------------|----------------------------------------------------------------------------|
| Silver nitrate + sodium chloride      | Silver chloride ( $\text{AgCl}$ )                                          |
| Barium chloride + potassium sulfate   | Barium sulfate ( $\text{BaSO}_4$ )                                         |
| Sodium nitrate + potassium chloride   | None (all possible products are soluble)<br>(in fact there is no reaction) |
| Copper(II) sulfate + sodium hydroxide | Copper(II) hydroxide ( $\text{Cu}(\text{OH})_2$ )                          |

## Part E: Practice Questions

- E1** Lead(II) nitrate solution is added to dilute sulfuric acid. [1]  
(a) Name the precipitate formed.  
Lead(II) sulfate
- (b) Write the ionic equation, with state symbols, for the formation of the precipitate. [2]  
 $\text{Pb}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{PbSO}_4(\text{s})$
- E2** Describe how you would prepare a pure, dry sample of lead(II) sulfate from lead(II) nitrate solution. [4]  
Add excess dilute sulfuric acid (or sodium sulfate solution) to the lead(II) nitrate solution. Filter to collect the white precipitate as the residue. Wash it with distilled water to remove soluble impurities. Dry it between filter papers (or in a warm oven).
- E3** Explain why lead(II) carbonate cannot be made by reacting a lead compound with an acid, and state the method that should be used. [2]  
 $\text{PbCO}_3$  is insoluble; acid reactions are used to make soluble salts. It must be made by precipitation: mix lead(II) nitrate solution with sodium carbonate solution, then filter, wash and dry.