KembloX™

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CLASSROOM AND LABORATORY ACTIVITIES

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C O N T E N T

Ionic Compounds modeling with the KembloX™ system

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Introduction

Atoms in compounds can bind together in various ways. This laboratory session is for modeling ionic compounds. In ionic compounds, atoms tend to become anions (ions that have more electrons than protons, and therefore are NEGATIVELY charged), or cations (ions that have fewer electrons than protons, and therefore are POSITIVELY charged). Based on the periodic table of elements, one can predict the type of ion associated with a given atom, especially for main group elements. Ionic compounds are compounds in which the atoms are held together by electrostatic attraction between anions (ions that are negative due to an **excess** of electrons) and cations (ions that are positive due to a **deficit** of electrons). This charge difference is illustrated in KembloX™ by using blocks with posts (extra electrons) and wells (electron deficit). KembloX™ helps students visualize the formula unit of ionic compounds, in which the total transfer of electrons occurs. Also, it illustrates the difference between compounds in which the cation can have different charge (e.g. Iron(II) and Iron(III), or copper(I) and copper(II)). A formula unit is the simplest formula for an ionic compound.

Description

KembloX™ contains a color-coded chart comprising a list of anions and cations. Monatomic ions are marked with colors in the periodic table area of the chart, while the polyatomic ions are listed separately. The charges of the ions covered by this kit are presented in the chart by color stripes in their Periodic Table box, and by color in the list of polyatomic ions. The colors correspond to the common charge of the ion (if more than one charge is possible, then two stripes appear in the box, with the most common charge in the upper position). The shaded area in the periodic table indicates that the respective elements result in monatomic anions. Formula units for any combination of two ions that contain color in the chart can be built based on the present kit; that means over 3500 ionic compounds.

In addition to the color coded chart, the KembloX™ system also comprises blocks similarly color-coded, according to the **number** of charges: one, two, three, or four charges. The same color is used whether the charges are positive (deficit of electrons) or negative (excess electrons); the monatomic anions are shaded in the periodic table, while the charge is explicit in the list of polyatomic ions. Extra electrons (negative charges) are represented by posts; thus the blocks with posts represent anions. The positive charges (lack of electrons) are represented by wells; hence blocks with wells represent cations.

The full kit comprises six four-charge units (three anions and three cations), eight three-charge units (four anions and four cations), six two-charge units (three anions and three cations), and eight one-charge units (four anions and four cations). This kit covers all the possible ionic formula units. One of each is presented below:

Cations Anions

Once assembled in a valid representation of a formula unit, one can tell anions from cations from the signs engraved on the bottom of the blocks.

Safety

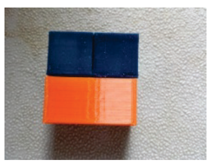
No special safety measures are necessary, except the common sense ones (e.g. do not put the blocks in your mouth, etc.).

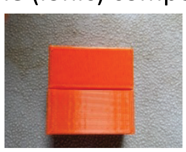
Procedure

Rules of the game

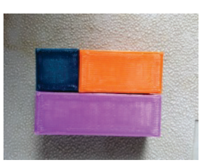
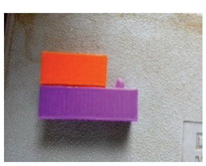
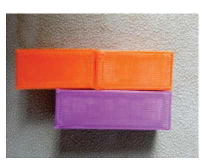
A valid representation of a formula unit will use a combination of blocks, assembled according to the following criteria:

a) The model of the formula unit has no wells or posts exposed; this ensures the electrical neutrality of the compound.
b) The model of the formula unit has one type of cation and one type of anion. KembloX™ does not cover double salts, such as dolomite $CaMg(CO_3)_2$. This does not limit the number of ions involved, as for example in Ca_3P_2, with a total of 5 ions.

For example the (ionic) compound of calcium (calcium ion) and chlorine (chloride ion), calcium chloride, would look like:  therefore the formula would be $CaCl_2$.

As another example, the (ionic) compound of calcium (calcium ion) and oxygen (oxide ion), calcium oxide, would look like:  therefore the formula would be CaO.

The three formula units shown below are invalid constructs: the first one (leftmost) has two dissimilar cations (or two dissimilar anions), the second one has an unbalanced negative charge, and the third has an unbalanced positive charge.

One kit is sufficient for any ionic compound comprising the color-coded species covered in the chart included in the KembloX™ system.

Activity

Each team will have a KembloX™ system. Each team will receive several slips describing the formula units to be built. After finishing each model, including the hand-drawn sketch, the compound will be inspected and graded by the instructor. The team can proceed to the next model.

A typical slip will have enough information to have all the boxes completed by the student; the type and/or the amount of information provided/required is at the instructor's discretion. An example is provided below.

Example:

Assignment slip

Student Name1 Name2

	CATION	ANION	Compound
Formula			
Name			Sodium nitride

Sketch (approximately) the ions and the compound

Student-filled slip:

Student Name1 John Deer Name2 Jane Doe

	CATION	ANION	Compound
Formula	Na^+	N^{-3}	Na_3N
Name	Sodium	Nitride	Sodium nitride

Sketch (approximately) the ions and the compound

The KembloX™ Game

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OBJECTIVE

Familiarize students with the structure and nomenclature of ionic compounds.

INTRODUCTION

Hands-on instruction is an important component in Chemical Education. KembloX™, described at the site https://kemblox.wordpress.com, or on YouTube (https://www.youtube.com/watch?v=4kobcy1qmWo), is a system for modeling multiple aspects of the ionic compounds' chemistry. This work describes an application used not only for instructor-supervised instruction, but also for learning by discovery. For the latter aspects, students build the models and then "discover" the corresponding chemistry of the compounds. The KembloX™ game addresses students and educators familiar with KembloX™ and has the following educational advantages:

- It gives students ownership of the learning process
- It has a factor of randomness and surprise, by using a four-sided spin top
- The gambling aspect of luck has been eliminated, the emphasis being on knowledge and understanding of the chemistry of ionic compounds
- It is a valuable tool for learning by discovery

MATERIALS

Full KembloX™ system, which comprises a color-coded chart (common ions with charge 1-4), 28 blocks colored with the same code as the chart, and a four-sided spinning top. Also pen, paper forms (instructor-provided), stopwatch.

PROCEDURE

The students are divided into two or more competing sides (players or teams). Two members from different sides will be designated "spinners": one for cations, and one for anions, respectively (to avoid blaming one another). The game may involve two or more teams, as long as only two spinners are involved.

The cation spinner spins the top and the charge of the cation will be the one corresponding to the color exposed. The anion spinner spins the top and the charge of the anion will be the one corresponding to the color exposed.

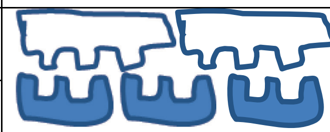
Once both cation and anion are randomly selected, the stopwatch is started, and the anions and the cations corresponding to the respective exposed colors are selected based on the chart, which is an intrinsic part of the kit. The designated writer in each team starts filling in the forms, after consultation with the rest of the team. After the time period assigned by the instructor lapses, everybody puts the pens down and the results are tallied. The team with most correct answers wins the competition. In case of a draw, the errors are tallied, and the team with the fewest errors prevails. The rewards are decided by the instructor. Alternatively, the instructor may assign a certain number of ionic compounds and the winner is the first team that presents the largest number of **correct** answers.

The amount of information requested by the instructor can vary and it is suggested that it be included in forms, as illustrated in the following example.

The forms may have the following entries:

Charge of the cation		Charge of the anion		Formula unit	Full name of the compound	Sketch
Name	Symbol	Name	Symbol			

A filled-up entry in the form above might look as follows:

Charge of the cation	+2 (orange)	Charge of the anion	-3 (purple)	Formula unit	Full name of the compound	Sketch
Name	Symbol	Name	Symbol			
Calcium	Ca^{+2}	Phosphide	P^{-3}	Ca_3P_2	Calcium Phosphide	
Copper(II)	Cu^{+2}	Phosphide	P^{-3}	Cu_3P_2	Copper(II) Phosphide	

Notes. A) The names of anions must be the full correct name (*e.g.* iodide, not iodine). B) The Stock naming must include the Roman numerals.

Metathesis reactions, Full Ionic Equation, Net Ionic Equation, Spectator Ions Using Kemblox™

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Objective Illustration of the following terms and concepts: metathesis reactions, spectator ions, full ionic equation, net ionic equations.

Introduction

Metathesis reactions, or double exchange reactions, are reactions between two ionic compounds in which the anion of one substance is exchanged for the anion of the other substance. An important class of metathesis reactions is the class of reactions in which an insoluble precipitate is formed. A schematic representation of these reactions is:

AB(aq) + CD(aq) →AD(s) +CB(aq)

In this laboratory session one will use Kemblox™ to model this type of reactions, and several important terms associated with them.

Safety – No special safety measures need to be taken.

Materials

Two KembloX™ kits. For convenience, we'll call them "reactant kit" and "product kit", respectively. Two kits ensure enough blocks to allow for comparison of the reactants with the products.

Solubility chart (https://kemblox.org/solubility-and-dissolution/, or a traditional one from the textbook).

Rubber bands (optional).

Erasable pen and erasing pad (alternatively one can use preprinted stickers with element symbols, or dry erase stickers to affix to the blocks) or any other means to temporarily assign chemical identity to the blocks.

Procedure

Write the balanced metathesis equation, as assigned by instructor:

AB(aq) + CD(aq) →AD(s) +CB(aq)

i.e.

Soluble salt 1 + Soluble salt 2 → Insoluble salt 3 + soluble salt 4

e.g.

Na_2SO_4(aq) + $CaCl_2$(aq) →$CaSO_4$(s) + 2 NaCl(aq)

Divide the workspace into the "reactant side" on the left, a "solution region" in the middle, and a "product side" on the right. Using the reactant kit, mark the ions (with the marker) with their chemical identity (marking two of the ions, an anion and a cation, would generally suffice).

1) With blocks from the first kit, on the reactant side, build the reactants, Na_2SO_4 and $CaCl_2$, respectively. Draw a schematic representation of the formula units involved. Make sure to mark (with the marker) at least the cation from one species and the anion from the other.
2) Separate the ions in the solution region. Make sure that the **all** ions are completely separated. Upon dissolution, the ions separate completely. In the given example:

$Na_2SO_4 + CaCl_2 \rightarrow 2\ Na^+ + SO_4^{2-} + Ca^{2+} + 2\ Cl^-$

Thus, in the solution region, one has the six ions: 2 Na^+, SO_4^{2-}, Ca^{2+}, and 2 Cl^-

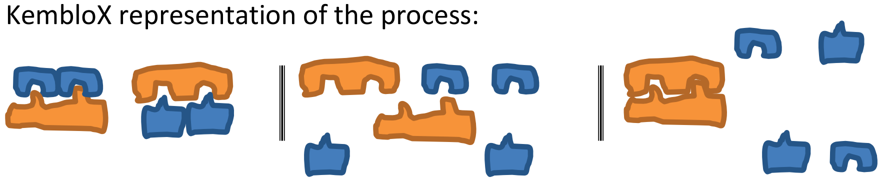
3) Select, from the products side, blocks representing the ions present in the "solution region" (the six ions), and build the insoluble product (to emphasize the lack of solubility, one can use a rubber band to hold the ions together). The other ions will remain separated, as being dissolved.

$2\ Na^+\ (aq) + SO_4^{2-}\ (aq) + Ca^{2+}\ (aq) + 2\ Cl^-(aq) \rightarrow CaSO_4\ (s) + 2\ Na^+\ (aq) + 2\ Cl^-\ (aq)$

One has modeled the metathesis reaction, and illustrated *all* the ions involved. We call the equation that involves **all** the ions the **Full Ionic Equation**:

$2\ Na^+\ (aq) + SO_4^{2-}\ (aq) + Ca^{2+}\ (aq) + 2\ Cl^-\ (aq) \rightarrow CaSO_4\ (s) + 2\ Na^+\ (aq) + 2\ Cl^-\ (aq)$

KembloX representation of the process:



Na_2SO_4 $CaCl_2$ $CaSO_4$

By comparing the reactant side with the product side, we'll notice that there are ions that stay the same. They are called **Spectator Ions.** They are the ions left separated on the product side. In our example, they are Na^+ and Cl^-.

If the spectator ions are removed from both the reactant side and the product side, then we are left with the **net ionic equation:**

$SO_4^{2-}\ (aq) + Ca^{2+}(aq) \rightarrow CaSO_4\ (s)$

The instructor will assign tasks by selectively filling some of the columns in the following table and ask the students to fill in the blank spaces.

Soluble 1	Soluble 2	Insol. 3	Soluble4	Full Ionic	Spect.	Net ionic
Na_2SO_4	$CaCl_2$	$CaSO_4$	NaCl	$2\ Na^+\ (aq) + SO_4^{2-}\ (aq) + Ca^{2+}\ (aq) + 2\ Cl^-\ (aq) \rightarrow CaSO_4\ (s) + 2\ Na^+\ (aq) + 2\ Cl^-\ (aq)$	Na^+, Cl^-	$SO_4^{2-}\ (aq) + Ca^{2+}(aq) \rightarrow CaSO_4\ (s)$

For example, the information provided by the instructor might be

Soluble 1	Soluble 2	Insol. 3	Soluble4	Full Ionic	Spect.	Net ionic
NaCl	$AgNO_3$					

Limiting Reagent, Theoretical Yield, and Actual Yield with Kemblox™

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Objective Illustration of the following terms and concepts: limiting reactant, excess reactant, theoretical yield, and actual yield.

Introduction

The target objectives will be illustrated based on a metathesis reaction.

Metathesis reactions are double exchange reactions between ionic compounds, following the pattern:

AB(aq) + CD(aq) → AD(s) + CB(aq)

In many real life instances the available amounts are different than the stoichiometric ones. For example, assume that the above equation is balanced. If, however, we start with TWO moles of AB and ONE mole of CD then we obtain only ONE mole of AD(s). After the reaction, we would:

- Have used all CD – this would be the **LIMITING REACTANT**, because it limits the amount of product formed
- Have at least ONE mole of AB left over - this would be the **EXCESS REACTANT**

Safety – No special safety measures are needed.

Materials
KembloX systems, sufficient to ensure the number of necessary blocks (ions) assigned by the instructor.
Solubility chart https://kemblox.org/solubility-and-dissolution/, or a conventional solubility chart from the textbook).
Erasable pen and erasing pad (alternatively one can use preprinted stickers with element symbols, or dry erase stickers to affix to the blocks) or any other means to assign chemical identity to the blocks.
Rubber bands (optional).

Procedure

Write the balanced metathesis equation

AB(aq) + CD(aq) →AD(s) +CB(aq)

i.e.

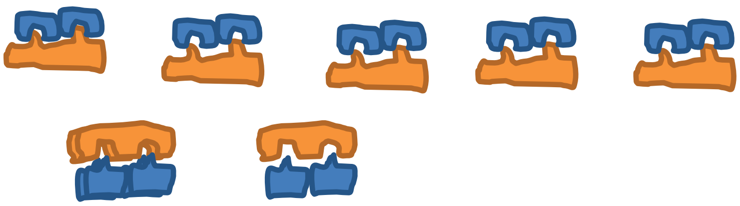
Soluble salt 1 + Soluble salt 2 → Insoluble salt 3 + soluble salt 4

E.g. Na_2SO_4 (aq) + $CaCl_2$ (aq) →$CaSO_4$ (s) + 2 NaCl (aq)

The instructor will assign the identity of the substances (AB and CD), and their respective amounts, in moles. For example, one could start with 5 Na_2SO_4 and 2 $CaCl_2$.

Divide the workspace into the "reactant side" on the left, a "solution region" in the middle, and a "product side" on the right. Using the reactant kit, mark the ions with their chemical identity (marking the cations for each formula unit present for one reactant, and the anions for each formula unit present of the other reactant, would generally suffice).

1) Using KembloX, build the assigned number of formula units for reactants, Na_2SO_4 and $CaCl_2$, respectively, and sketch their formula units represented by Kemblox™.



2) Upon dissolution, the ions separate completely:

5 Na_2SO_4 + 2 $CaCl_2$ → 10 Na^+ + 5 SO_4^{2-} + 2 Ca^{2+} + 4 Cl^-

Thus, in the solution region, one has the 21 ions: 10 Na^+, 5 SO_4^{2-}, 2 Ca^{2+}, 4 Cl^-

3) Replicate, on the products side, the 21 ions and build the insoluble product (to emphasize the lack of solubility, one may use the rubber band to hold the ions together). The other ions will remain separated, as being dissolved.

10 Na^+ + 5 SO_4^{2-} + 2 Ca^{2+} + 4 Cl^- →2 $CaSO_4$ (s) + 10 Na^+ + 4 Cl^- + 3 SO_4^{2-}

If the unaffected ions (those whose number or state is not changed) are eliminated, the ionic equation becomes

5 SO_4^{2-} + 2 Ca^{2+} →2 $CaSO_4$ (s) + 3 SO_4^{2-}

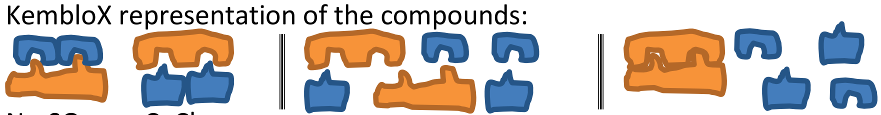
Here, it becomes apparent that the limiting reactant is the one containing Ca^{2+}, and the excess reactant is the one containing SO_4^{2-}, with 3 moles of the SO_4^{2-} -containing remaining reactant.

In real life situations, the amount of product is usually less than the one predicted (**theoretical yield)**; this amount is called the **actual yield.** The formula for calculating the percent actual yield is:

ACTUAL YIELD = 100 x (actual amount of product resulted/predicted amount of product)

The instructor will assign tasks by selectively filling the columns in the following table, as well as the Actual yield OR the actual amount of product.

For the given example, a filled table would look as follows:

<table>
<tr><td colspan="11">Balanced chemical equation: Na_2SO_4 (aq) + $CaCl_2$ (aq) →$CaSO_4$ (s) + 2NaCl (aq)</td></tr>
<tr><td colspan="10">KembloX representation of the compounds:

Na_2SO_4 $CaCl_2$</td><td>Instr.
Chk.
BAB</td></tr>
<tr><td>AB</td><td>Mole AB</td><td>CD</td><td>Mole CD</td><td>AD</td><td>Mole AD</td><td>Limiting</td><td>Mole excess</td><td>Theoretical yield</td><td>ACTUAL * (instructor)</td><td>Act. Amt.</td></tr>
<tr><td>Na_2SO_4</td><td>5</td><td>$CaCl_2$</td><td>2</td><td>$CaSO_4$</td><td>2</td><td>$CaCl_2$</td><td>3</td><td>2 mol $CaSO_4$</td><td>75%</td><td>1.5 mol $CaSO_4$</td></tr>
<tr><td colspan="11">*The ACTUAL yield OR the actual amount must be assigned by the instructor, unless the actual reaction is performed.</td></tr>
</table>

The **theoretical yield** of product is thus 2 moles of $CaSO_4$(s).

An example of instructor-provided assignment sheet might be:

<table>
<tr><td colspan="11">Balanced chemical equation:</td></tr>
<tr><td colspan="10">KembloX representation of the compounds:</td><td>Instr.
Chk.</td></tr>
<tr><td>AB</td><td>Mole AB</td><td>CD</td><td>Mole CD</td><td>AD</td><td>Mole AD</td><td>Limiting</td><td>Mole excess</td><td>Theoretical yield</td><td>ACTUAL * (instructor)</td><td>Act. Amt.</td></tr>
<tr><td>K_2SO_4</td><td>4</td><td>$PbCl_2$</td><td>3</td><td></td><td></td><td></td><td></td><td></td><td>75%</td><td></td></tr>
<tr><td colspan="11">*The ACTUAL yield OR the actual amount must be assigned by the instructor, unless the actual reaction is performed.</td></tr>
</table>