Sticky Ions

Dissociation of Ionic Compounds

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CHM 102: General Education Chemistry

- All students are non-science majors
- Most have had one year of high school chemistry
- 60-70 students per section
- Three 50-minute or two 75-minute lectures per week; no lab or discussion
- Mix of lecture and inquiry (mostly POGIL) activities

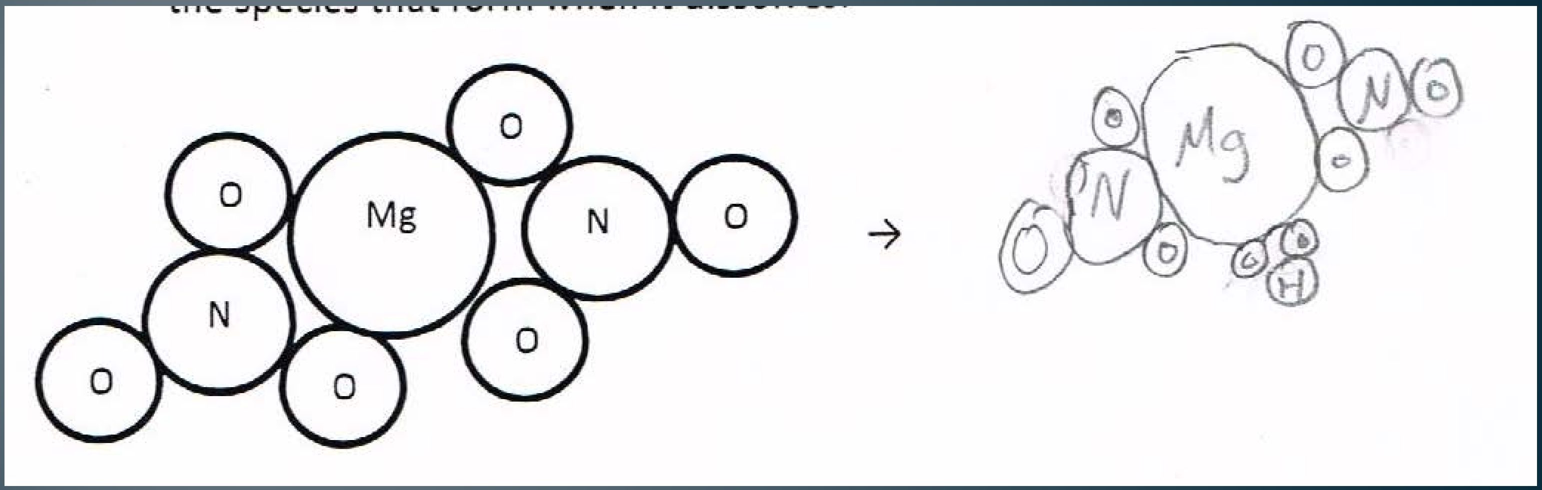
Rationale

- Students have a poor understanding of what is happening at the particulate level when ionic compounds dissolve.
- Misconceptions include:
- *Ionic pairs such as Na^+ and Cl^- are molecules.*

- Cachapuz, A.F. and Martins, I.P. (1987). High school students' ideas about energy of chemical reactions. In J. Novak and H. Helm, (eds.) *Proceedings of the International Seminar on Misconceptions in Science and Mechanics, Vol. 3, 60-68. (reported in Boo(1998)).*
- Kind, V. (2004). *Beyond appearances: Students' misconceptions about basic chemical ideas, 2nd edition,* School of Education, Durham University, UK. Self-published; available at http://www.chemsoc.org/pdf/LearnNet/rsc/miscon.pdf
- Taber, K. S. (1998). An alternative conceptual framework from chemistry education. *International Journal of Science Education 20*(5), 597-608.

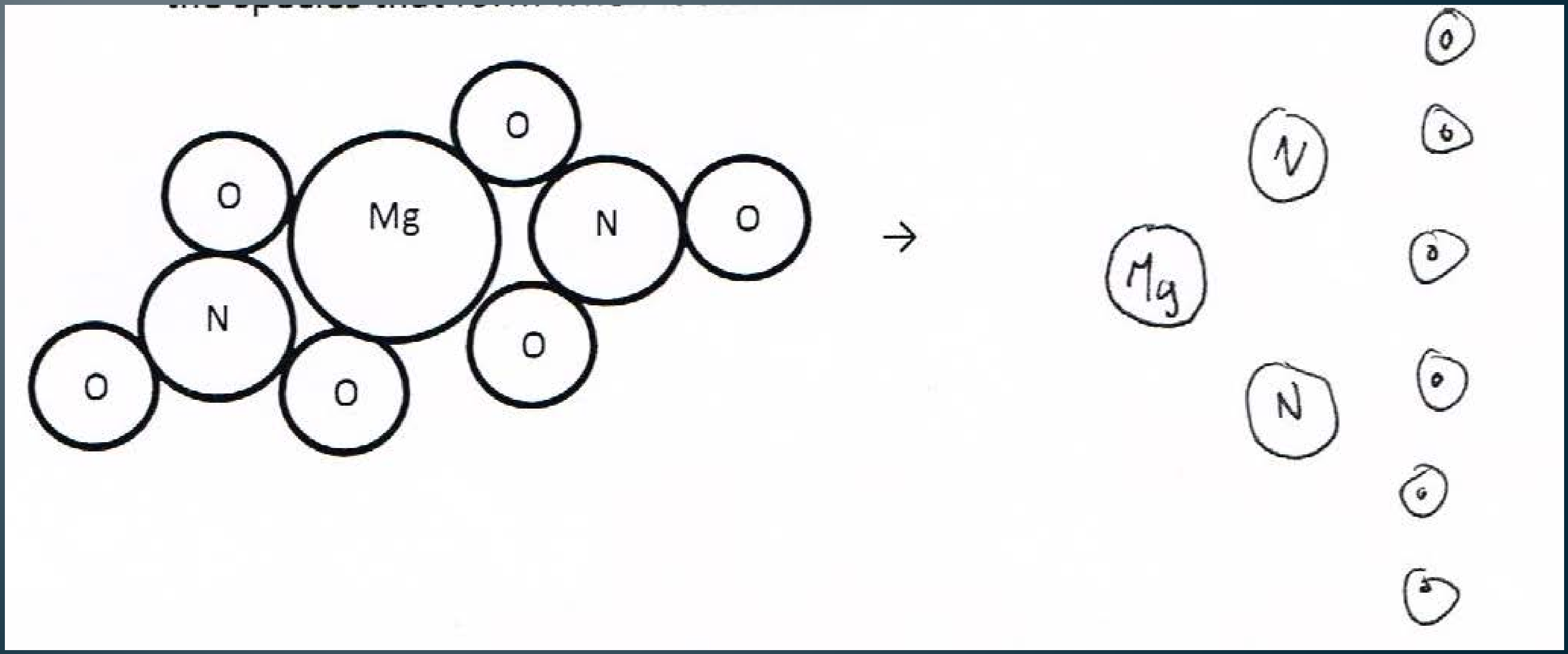
Rationale

- Compounds always remain intact (as whole molecules) when dissolving in water.



Rationale

- Compounds dissolving in water always break down into individual atoms (or monoatomic ions) when they dissolve.



Rationale

- Students struggle to write symbolic representations of this process.

$$Mg(NO_3)_2 \rightarrow \quad Mg \quad 2N \quad 6O$$

(solid)

$$Mg(NO_3)_2 \rightarrow Mg(NO_3)_2 H_2O$$

(solid)

$$Mg(NO_3)_2 \rightarrow Mg + (NO_3)_2$$

(solid)

Rationale

- Similar results reported in the following:
- Naah, B. M., & Sanger, M. J. *Chem. Educ. Res. Prac.* **2012** Retrieved from http://dx.doi.org/10.1039/C2RP00015F
- Smith, K. J. , Metz, P. A. *J. Chem. Ed.* **1996**, *73*, 233-235

Objectives

- The student will be able to predict what species form when ionic compounds dissolve in water.
- The student will be able to make a particulate-level sketch of the dissolving process and write a balanced symbolic equation.

Objectives

- The student will be able to describe the interactions between water molecules and ions.
- The student will be able to describe the difference between solutions of ionic compounds and solutions of polar-covalent compounds, particularly with respect to conductivity.

Requisite Prior Knowledge

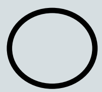
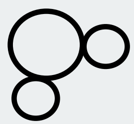
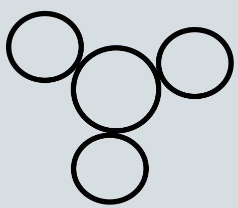
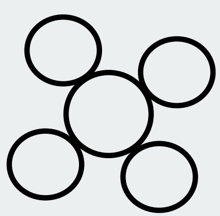
- Lewis dot structures
- Polarity of water molecules, placement of partial charges and hydrogen bonding
- Dissolving of polar-covalent compounds
- Ions
  - How they differ from atoms
  - Predicting charge on ions
  - Transition metal ions
  - Polyatomic ions

Sticky Ions

- Guided inquiry activity using magnetic models to illustrate interactions of ions with each other and with water molecules.
- The models used in this activity are modified from those described in the following:

  Davies, W. G. *J. Chem. Ed*. **1991**, *68*, 245-246.

The Models:

Magnet Shape	Representing
	Any monoatomic cation or anion Ex. Li^{+} Ca^{2+} F^{-}
	Water Molecules
	NO_3^{-} CO_3^{2-} SO_3^{2-}
	SO_4^{2-} PO_4^{3-}

The Models: Limitations

- Not three-dimensional – note difference between flattened shape of polyatomics compared to actual molecular geometry
- Size – different atoms/ions are different sizes
- Strength of interactions – all modeled forces (hydrogen bonding, ion-dipole and ion-ion) appear the same.

Review and Predictions

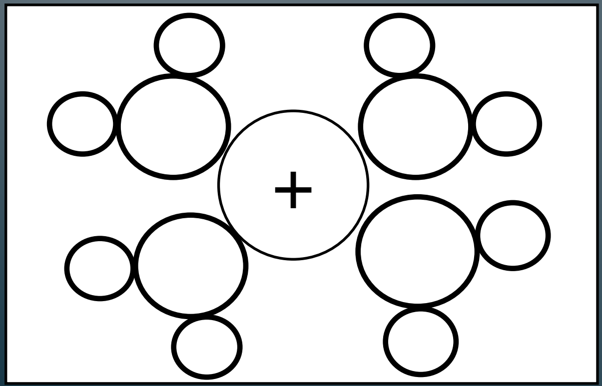
- Sketching hydrogen bonding
- Draw Lewis dot structures for polyatomic ions
- Predicting how water molecules will arrange around ions
- Predict products for $Mg(NO_3)_2$ dissolving

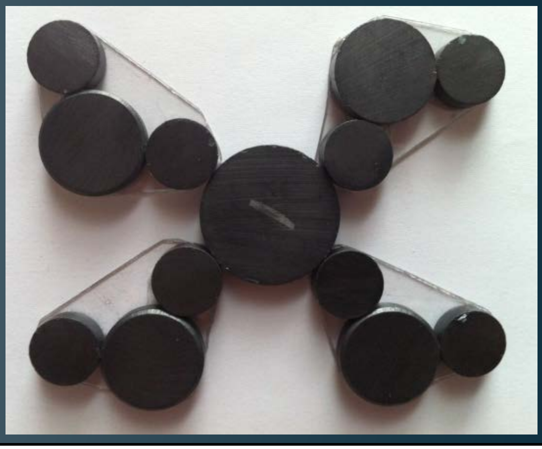
Models Part A: Monoatomic Ions

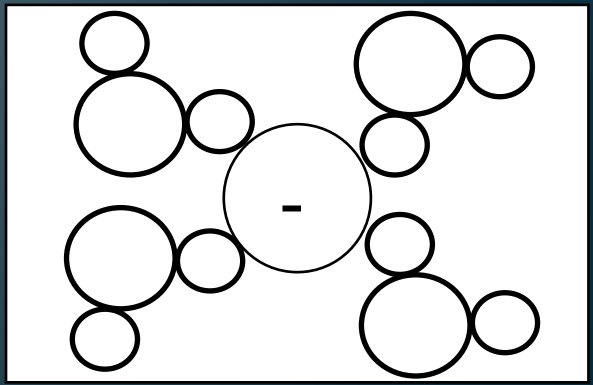
- From a list of compound names, write the correct formula for each ionic compound.
- Build an ionic compound model using three cations and three anions.

Models Part A: Monoatomic Ions

- Model interaction between water molecules and monoatomic ions.

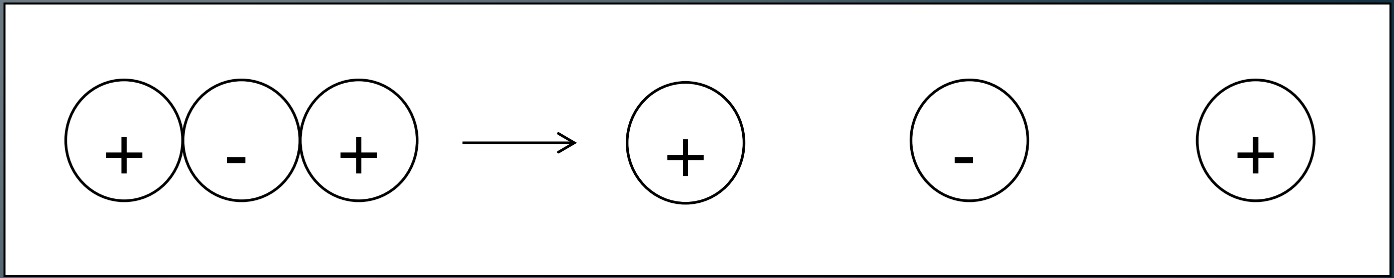






Models Part A: Monoatomic Ions

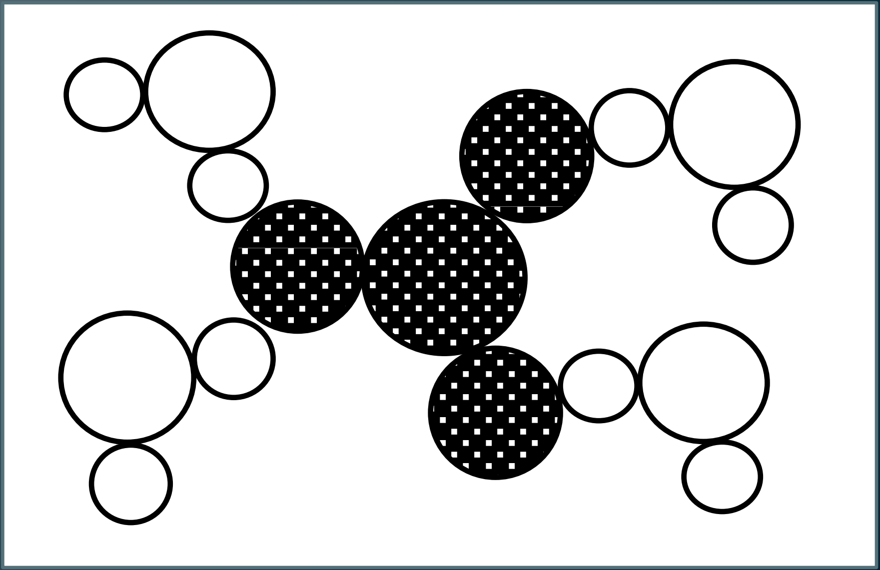
- Model dissolving of various ionic compounds.
- 



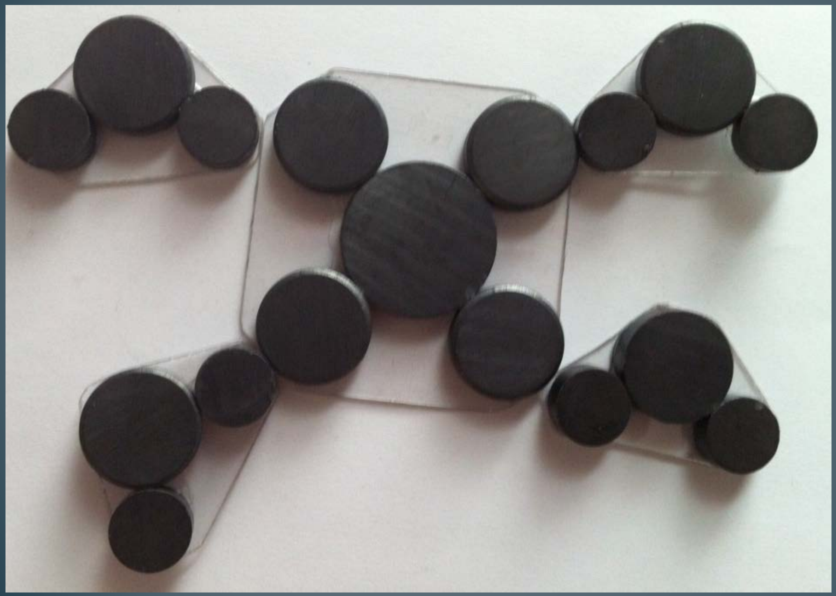
- Write corresponding symbolic expression for dissolving.
- $Li_2O_{(s)} \rightarrow 2Li^{+} + O^{2-}$

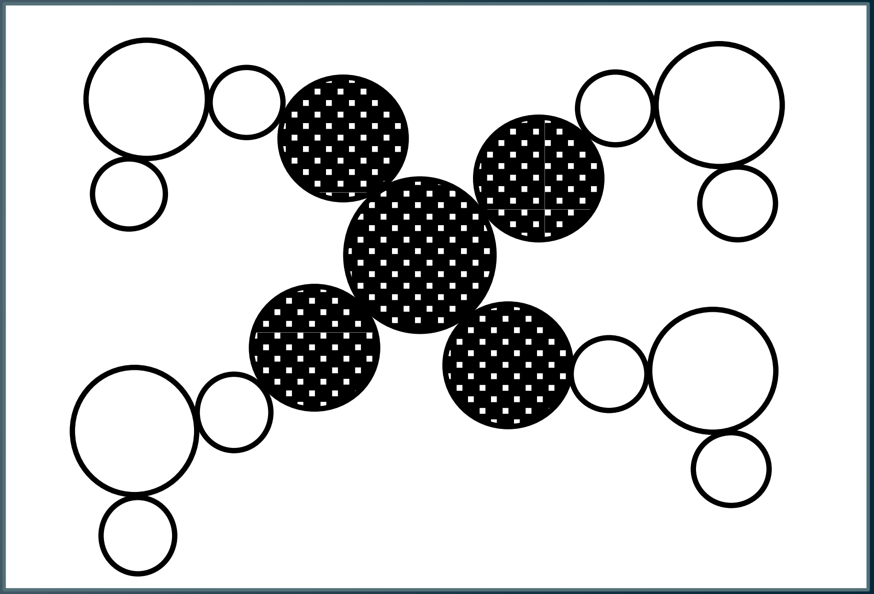
Models Part B: Polyatomic Ions

- From a list of compound names, write the correct formula for each ionic compound.
- Model interaction between water molecules and polyatomic ions.



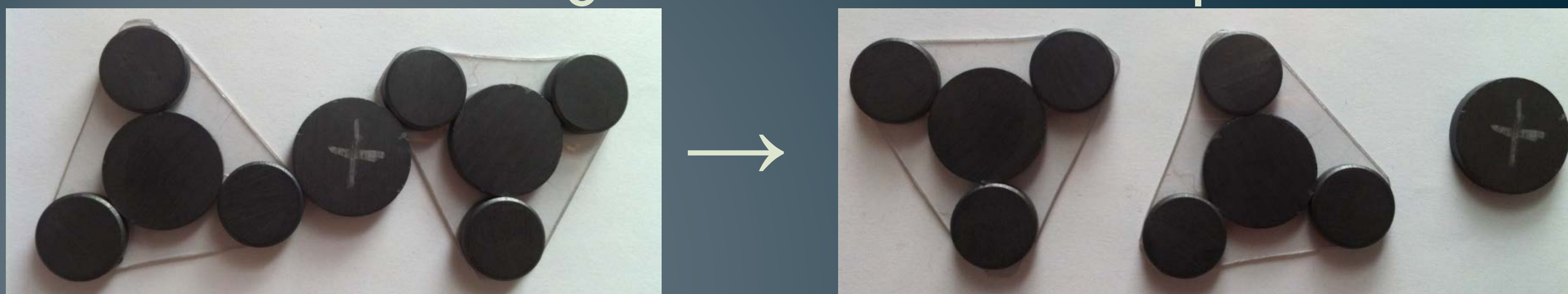
Models Part B: Polyatomic Ions

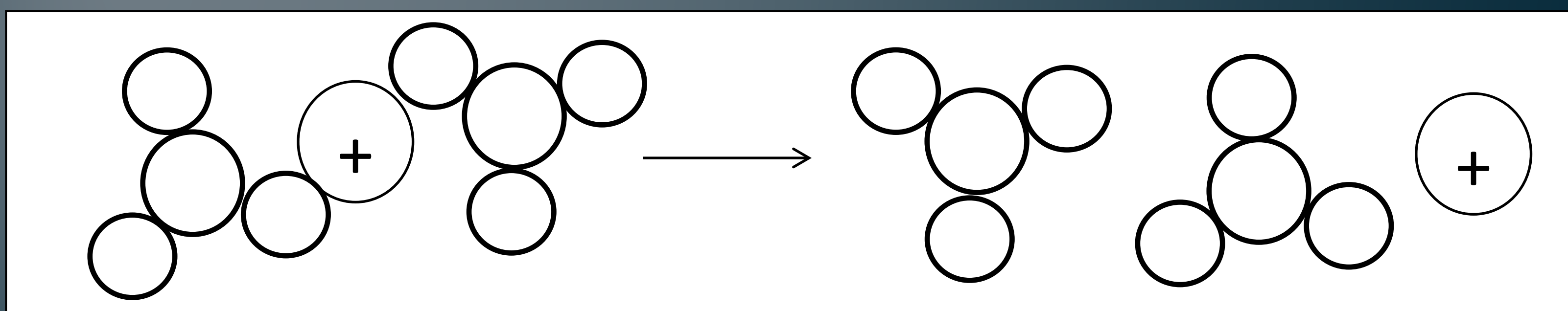




Models Part B: Polyatomic Ions

- Model dissolving of various ionic compounds.





- Write corresponding symbolic expression.
- $Fe(NO_3)_{2(s)} \rightarrow Fe^{2+} + 2NO_3^-$

Analysis Part A: Monoatomic Ions

- Students articulate why ionic compounds dissolve, based on the modeled interactions with water molecules.
- Students are asked why not all ionic compounds dissolve.

Analysis Part B: Polyatomic Ions

- Students develop a guideline for determining what species form when an ionic compound containing a polyatomic ion dissolves.
- Students apply their guideline to the dissolving of $(NH_4)_2SO_4$, this time without building the model.

Going Further: Conductivity

- Does water conduct electricity?
- Conductivity demo or interactive stations:
  - Conductivity meter
  - Deionized water
  - Tap water
  - Sugar water
  - Salt water

Evaluation of Activity

- Fall 2011: Activity carried out with two sections of CHM 102
- Winter 2012: Activity modified to be demonstrated models only, instead of hands-on, and carried out with one section of CHM 102
- All classes given a pre-test, post-test and several related questions on the course final
- Winter 2012: Post-test also given to two sections taught by another professor, without activity

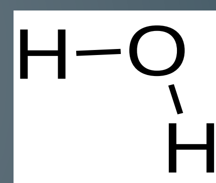
Evaluation of Activity

- What happens when the ionic compound sodium sulfate (Na_2SO_4) dissolves in water?
  a. Sodium sulfate molecules separate from the bulk solid and mix with the water.
  b. Sodium ions and sulfate ions separate from the bulk solid and mix with the water.
  c. Sodium ions, sulfide ions and oxide ions separate from the bulk solid and mix with the water.
  d. Sodium and sulfate react with water to make NaOH and H_2SO_4.
  e. Nothing. Ionic compounds can't dissolve in water.

Evaluation of Activity

Section			% correct: Multiple Choice Question	
#	Description	n	Pre	Post
F11 04	hands-on	47	32%	87%
F11 02	hands-on	45	27%	100%
W12 03	demo	44	25%	93%
W12 01	comparison	27	----	30%
W12 02	comparison	28	----	71%

Evaluation of Activity

- For the ions shown below, sketch how water molecules would interact with them if they were in solution. You may use the representation shown for your waters: 

Evaluation of Activity

Section			% correct: Drawing Waters Around Ions		
#	Description	n	Pre	Post	Final
F11 04	hands-on	47	40%	91%	91%
F11 02	hands-on	45	53%	87%	87%
W12 03	demo	44	50%	82%	86%
W12 01	comparison	27	----	15%	----
W12 02	comparison	28	----	18%	----

Evaluation of Activity

- Shown below is the beginning of a reaction equation expressing what happens when magnesium nitrate dissolves in water. Complete the equation by writing the species that form (products).

$Mg(NO_3)_2 \rightarrow$

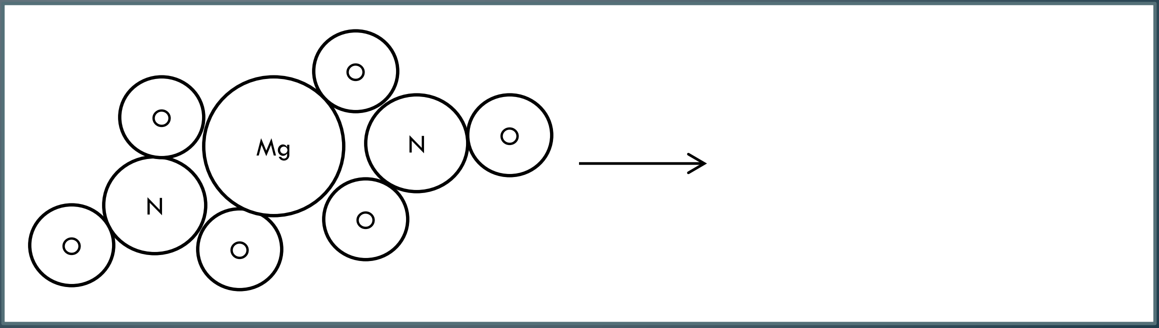
(solid)

Evaluation of Activity

Section			% correct: Balanced Equation		
#	Description	n	Pre	Post	Final
F11 04	hands-on	47	26%	83%	68%
F11 02	hands-on	45	9%	89%	64%
W12 03	demo	44	18%	82%	64%
W12 01	comparison	27	----	7%	----
W12 02	comparison	28	----	14%	----

Evaluation of Activity

- Shown below is a molecular representation of magnesium nitrate. Based on the reaction you wrote above, draw the species that form when it dissolves.



Evaluation of Activity

Section			% correct: Drawing Ionic Compound Dissolving		
#	Description	n	Pre	Post	Final
F11 04	hands-on	47	30%	94%	81%
F11 02	hands-on	45	27%	100%	87%
W12 03	demo	44	27%	93%	86%
W12 01	comparison	27	----	19%	----
W12 02	comparison	28	----	29%	----

Acknowledgements

- GVSU Target Inquiry Instructors and Teacher Colleagues
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