A Guide to Reactions in Aqueous Solution

Teaching Approach

In order to understand reactions in aqueous solutions, we first need to understand the solvent – water. So we first need to explain the structure of the water molecule and how the atoms in the water molecule are bonded together, as well as how the molecules interact with each other. This is important as it governs how water reacts with other substances.

To form a solution, a solute (in this case an ionic solid) is dissolved in a solvent. Therefore we must understand the dissolution process. We also need to know that certain substances dissolve better than others. This is known as a solubility rule.

One of the properties of aqueous solutions is the conduction of electricity. If possible, it would be great if the learners could do an experiment where they test the conductivity of different solutions (as shown in the videos) as well as how the concentration affects the conductivity of electricity. Learners need to understand that electricity flows due to ions that are free to move in water.

A good understanding of reactions that occur when two aqueous solutions are mixed depends on knowing the physical and chemical properties of substances, as well as the differences between physical and chemical change.

Small experiments that help to demonstrate the difference between chemical and physical change within reactions can be set up. These need to then be related to what happens when we dissolve substances in water, such as whether or not the reactions give off heat energy or take it in, as well as whether or not the products are different in phase from the reactants.

We look at different types of reactions that occur when we mix two aqueous solutions. This is a great opportunity for the learners to do halide ion tests, as well as tests for sulfate ions and carbonate ions. The learners can make a chart of their results and this will help them remember the tests and the results.

We also investigate a redox reaction. The CAPS document does say that this should be on a very basic level. The breaking up of water into oxygen and hydrogen, and the tests to prove the presence of these gases is a fairly easy demonstration to set up, as well as a particularly effective one to show how we can decompose a compound into its constituent elements. It can be shown that there has been a change in charge in the atoms during the reaction, proving that this is a redox reaction.
Video Summaries

Some videos have a ‘PAUSE’ moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given.

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day’s lesson; if desired, learners can be given specific questions to answer in preparation for the next day’s lesson

1. **The Water Molecule**
   
   In this lesson we learn about water and its structure. We learn about the interatomic forces that hold water together, and how this leads to the intermolecular electrostatic forces, namely hydrogen bonds.

2. **Dissolving Ionic Solids**
   
   In this video we look at how an ionic substance dissolves in water. We recap ionic substances and what makes an ionic bond. The process of dissolution and hydration are explained in detail.

3. **Electricity in Liquids**
   
   This video covers electrolysis. Both electrolysis and electrolytes are defined. Experiments are done to discover that the nature of solute affects electrolysis, and that ionic solutions are good conductors of electricity.

4. **Chemical and Physical Changes**
   
   In this video we cover the difference between chemical and physical properties of substances. In addition, chemical and physical changes in reactions are explained.

5. **Chemical vs Physical Changes in Aqueous Solutions**
   
   In this video we look specifically at physical and chemical changes that occur when substances are dissolved in water. An experiment is done where the temperature during the reaction is measured.
6. Precipitation Reactions
   In this lesson ion-exchange reactions are introduced. We specifically investigate precipitation reactions. Tests for halides, sulfates and carbonates are thoroughly covered.

7. Gas Forming Reactions
   The second type of ion-exchange reactions, gas forming reactions, is introduced. We show how a carbonate and an acid form a salt, water and carbon dioxide, while a metal plus an acid always forms a salt and hydrogen.

8. Acid Base Reactions
   The third type of ion-exchange reaction, acid-base reactions, is introduced. The point that these are proton transfer reactions is covered. Basic differences between acids and bases are covered.

9. Redox Reactions
   Redox reactions are identified as electron transfer reactions. The fact that redox reactions can be identified by the change in charge in atoms as they change from reactants to products is explained and demonstrated.
## Resource Material

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<td><a href="http://witcombe.sbc.edu/water/chemistrystructure.html">http://witcombe.sbc.edu/water/chemistrystructure.html</a></td>
<td>A lesson on the chemistry of water</td>
</tr>
<tr>
<td>2.</td>
<td>Dissolving Ionic Solutions</td>
<td><a href="http://www.chemguide.co.uk/atoms/bonding/electroneg.html">http://www.chemguide.co.uk/atoms/bonding/electroneg.html</a></td>
<td>This page explains what electronegativity is, and how and why it varies around the Periodic Table.</td>
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<td>3.</td>
<td>Electricity in Liquids</td>
<td><a href="http://www.howstuffworks.com/electrolysis-info.htm">http://www.howstuffworks.com/electrolysis-info.htm</a></td>
<td>This page explains how electrolysis works</td>
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<td></td>
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<td><a href="http://www.youtube.com/watch?v=Tq1qOG9DoY">http://www.youtube.com/watch?v=Tq1qOG9DoY</a></td>
<td>This is a GCSE Science Revision on the electrolysis of a solution</td>
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<td><a href="http://chemistry.about.com/od/lecturenotesl3/a/chemphyschanges.htm">http://chemistry.about.com/od/lecturenotesl3/a/chemphyschanges.htm</a></td>
<td>This page defines the difference between physical and chemical changes.</td>
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<td>5.</td>
<td>Chemical Changes vs Physical Changes in Aqueous Solutions</td>
<td><a href="http://chemistry.about.com/od/matter/a/Is-Dissolving-Salt-In-Water-A-Chemical-Change-Or-Physical-Change.htm">http://chemistry.about.com/od/matter/a/Is-Dissolving-Salt-In-Water-A-Chemical-Change-Or-Physical-Change.htm</a></td>
<td>This page defines whether dissolving salt is a chemical change or a physical change.</td>
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<tr>
<td>6. Precipitation Reactions</td>
<td><a href="http://www.chemguide.co.uk/inorganic/group7/testing.html">http://www.chemguide.co.uk/inorganic/group7/testing.html</a></td>
<td>This page describes and explains the tests for halide ions (fluoride, chloride, bromide and iodide) using silver nitrate solution followed by ammonia solution.</td>
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<td><a href="https://everythingscience.co.za/grade-10/18-reactions-in-aqueous-solution/18-reactions-in-aqueous-solution-05.cnxml">https://everythingscience.co.za/grade-10/18-reactions-in-aqueous-solution/18-reactions-in-aqueous-solution-05.cnxml</a> plus</td>
<td>This page looks at two types of reactions that occur in aqueous solutions. These are ion-exchange reactions and redox reactions. Ion exchange reactions include precipitation reactions, gas forming reactions and acid-base reactions.</td>
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<tr>
<td>8. Acid Base Reactions</td>
<td><a href="http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/acidbase.html">http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/acidbase.html</a></td>
<td>This page looks at acid-base reactions and properties.</td>
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</tbody>
</table>
Task

Question 1
What is the solvent in an aqueous solution?

Question 2
With what type of bond are atoms in the water molecule held together?

Question 3
What are the intermolecular forces that allow water molecules to be attracted to each other?

Question 4
Is the process of dissolution a physical or chemical change?

Question 5
What is the definition of hydration?

Question 6
Write an ionic equation to show how potassium hydroxide dissolves in water.

Question 7
What do we call the transfer of electricity through a liquid?

Question 8
8.1 What is meant by the term "electrolyte"?
8.2 What determines the strength of an electrolyte?

Question 9
What are two factors that affect electrolysis?

Question 10
Which of the following solutions conduct electricity?

10.1 calcium chloride
10.2 copper sulfate
10.3 glucose
10.4 tap water

Question 11
Write down the chemical equations for the ion exchange reaction of the reactants below. (In each case, name the specific type of reaction).

11.1 sodium carbonate and nitric acid
11.2 potassium iodide and silver nitrate
11.3 sodium hydroxide and hydrochloric acid
Question 12
What are the three types of ion-exchange reactions we have learnt about in this series?

Question 13
What is a precipitation reaction?

Question 14
The test tubes marked X, Y and Z each contain a solution of an unknown sodium salt. The following observations are made during a practical investigation to identify the solutions in the test tubes:

a) A white precipitate is formed when silver nitrate is added to test tube Z.
b) A white precipitate is formed in test tubes X and Y after the addition of barium chloride.
c) The precipitate in test tube X dissolves in hydrochloric acid and a gas is released.
d) The precipitate in test tube Y is insoluble in hydrochloric acid.

14.1 Use the above information to identify the solutions in each of test tubes X, Y and Z.
14.2 Write a balanced chemical equation for the reaction taking place in test tube X before the addition of hydrochloric acid.

Question 15
You are required to do a practical exam and you are given the following chemicals: NaCl, MgBr₂, KI, Na₂CO₃, AgNO₃ and HCl.

15.1 Write down the names for each of the given formulae.
15.2 You add AgNO₃ to each of the solutions: NaCl, MgBr₂, KI and Na₂CO₃. What do you see?
15.3 Explain how you would interpret each of your observations.
15.4 Write a balanced equation for each of the reactions you performed above.
15.5 Explain how you would use HNO₃ solution to distinguish between the precipitates that are produced when silver nitrate is added to NaCl and Na₂CO₃.
Question 16
Write a balanced equation for the following reactions and say what the driving force is for each reaction:
16.1 Chlorine and sodium iodide
16.2 Sulfuric acid and potassium hydroxide

Question 17
Identify each of the following reactions and say what the driving force is for each reaction:
17.1 KBr(aq) + AgNO₃(aq) \rightarrow KNO₃(aq) + AgBr(s)
17.2 Zn(s) + 2HCl(aq) \rightarrow ZnCl₂(aq) + H₂(g)
Task Answers

Question 1
Water

Question 2
Polar Covalent

Question 3
Hydrogen bonds

Question 4
Physical change

Question 5
Hydration occurs if water is the solvent and the ions of the substance are surrounded by water molecules.

Question 6

\[ \text{KOH(s)} \rightarrow \text{K}^\text{(aq)} + \text{OH}^\text{−(aq)} \]

Question 7
Electrolysis

Question 8
8.1 An electrolyte is the solution or melted ionic compound with mobile charges that complete the circuit.
8.2 Concentration of the ions in solution determines the strength of the electrolyte.

Question 9
The presence of ions and the ability of these ions to move.

Question 10
10.1 Yes
10.2 Yes
10.3 No
10.4 Yes

Question 11
11.1 \( \text{Na}_2\text{CO}_3(aq) + 2\text{HNO}_3(aq) \rightarrow 2\text{NaNO}_3(aq) + \text{CO}_2(g) + \text{H}_2\text{O(l)} \)
11.2 \( \text{KI(aq)} + \text{AgNO}_3(aq) \rightarrow \text{AgI(s)} + \text{KNO}_3(aq) \)
11.3 \( \text{NaOH(aq)} + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)} \)

Question 12
Precipitation, gas forming, and acid base

Question 13
It is one in which an insoluble salt forms.
Question 14
14.1 X: Sodium carbonate
Y: Sodium sulfate
Z: Sodium chloride
14.2 \( \text{Na}_2\text{CO}_3(\text{aq}) + \text{BaCl}_2(\text{aq}) \rightarrow \text{BaCO}_3(\text{s}) + 2\text{NaCl}(\text{aq}) \)

Question 15
15.1 Sodium chloride, magnesium bromide, potassium iodide, sodium carbonate, silver nitrate and hydrogen chloride (hydrochloric acid)
15.2 \( \text{NaCl: white precipitate} \)
\( \text{MgBr}_2: \) pale yellow precipitate
\( \text{KI: Yellow precipitate} \)
\( \text{Na}_2\text{CO}_3: \) yellow precipitate
15.3 Precipitate colours give idea of what anion is present: white = chloride ions, pale yellow = bromide ions, yellow = iodide ions. All need to be confirmed with the addition of silver ions as carbonate ions also form a yellow/pale green precipitate.
15.4 \( \text{NaCl(aq)} + \text{AgNO}_3(\text{aq}) \rightarrow \text{NaNO}_3(\text{aq}) + \text{AgCl(s)} \)
\( \text{MgBr}_2(\text{aq}) + \text{AgNO}_3(\text{aq}) \rightarrow \text{AgBr(s)} + \text{Mg(NO}_3)_2(\text{aq}) \)
\( \text{KI(aq)} + \text{AgNO}_3(\text{aq}) \rightarrow \text{AgI(s)} + \text{KNO}_3(\text{aq}) \)
\( \text{Na}_2\text{CO}_3(\text{aq}) + \text{AgNO}_3(\text{aq}) \rightarrow \text{Ag}_2\text{CO}_3(\text{s}) + \text{Na}_2\text{NO}_3(\text{aq}) \)
15.5 Add HNO\(_3\). Nothing will happen to the precipitate formed from silver chloride, but the sodium carbonate will bubble giving off carbon dioxide gas.

Question 16
16.1 \( \text{Cl}_2(\text{g}) + 2\text{NaI(aq)} \rightarrow 2\text{NaCl(aq)} + I_2(\text{g}) \) gas forming
16.2 \( \text{H}_2\text{SO}_4(\text{aq}) + 2\text{KOH(aq)} \rightarrow 2\text{H}_2\text{O(l)} + \text{K}_2\text{SO}_4(\text{aq}) \) proton transfer

Question 17
17.1 Precipitation; forming of AgBr
17.2 Redox; transfer of electrons, or gas forming (hydrogen gas)
Acknowledgements

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