Science by Doing
Engaging students with science

# CHEMICAL


## LESSON PLANS

Australian Academy of Science

## Part 2 Reactions happen

| Activity No | Activity Name | Lesson type | Activity Description |
|---|---|---|---|
| 2.1 | What is a chemical reaction? | Engage, Explore & Explain<br>Hands-on<br>Medium | Students will carry out a series of chemical reactions and make observations to revise their understanding. |
| 2.2 | Conservation of mass | Explore & Explain<br>Hands-on & Digital<br>Long | Students will carry out a practical investigation to verify the law of conservation of mass in chemical reactions and investigate the work of Antoine-Laurent de Lavoisier. Word equations are introduced to represent chemical reactions. |
| 2.3 | Ionic compounds | Explore, Explain & Elaborate<br>Hands-on & Classroom<br>Long | Students will use hands-on and digital interactive simulations to model the electron configurations of atoms and ions to gain an understanding of ionic bonding. They will complete an experiment to investigate conductivity of solutions and learn the naming conventions for simple ionic compounds. |
| 2.4 | Writing chemical formulae | Explain & Elaborate<br>Digital & Classroom<br>Medium | Students will learn strategies for writing formulae for ionic compounds using the cross-over method and a worksheet. They will also be introduced to common polyatomic ions. |
| 2.5 | Sharing electrons | Explore, Explain & Elaborate<br>Classroom<br>Short | Students will use molecular models to discover how molecules are formed by the sharing of electrons. |
| 2.6 | It's falling apart | Explore, Explain & Elaborate<br>Hands-on<br>Long | Students will carry out a decomposition reaction as a first-hand investigation. |

| Activity No | Activity Name | Lesson type | Activity Description |
|---|---|---|---|
| **2.7** | Reactions in solution | Explore, Explain & Elaborate | Students will complete an experiment to investigate precipitation reactions. They will then use solubility rules to predict when precipitates will form. |
| | | Hands-on, Classroom & Digital | |
| | | Medium | |
| **2.8** | Reactions revised | Engage & Evaluate | Students will again play the game Celebrity Chemistry Hats to review their knowledge and understanding of Parts 1 and 2 of this unit. |
| | | Classroom | |
| | | Short | |

## 2.1 What is a chemical reaction?

**Lesson outcomes**

At the end of this activity students will be able to:

- carry out a risk assessment when planning an experiment
- identify when a chemical reaction has occurred by observing changes.

**What ideas might your students already have?**

Students will have studied chemical and physical changes in **Rock, Paper, Scissors**.

**Key vocabulary:**

Observation, precipitate.

**Equipment list**

**The CLASS will require:**

- Materials Safety Data Sheet (MSDS) (or SDS) for each chemical used.

**Each GROUP will require:**

- dropper bottles of dilute 2M sulfuric acid, 1M ammonium hydroxide solution, 1M copper sulfate solution
- copper oxide powder
- small pieces of clean magnesium ribbon and granulated zinc
- Bunsen burner and heating mat
- 4 medium test tubes
- test-tube holder
- test-tube rack
- matches
- spatula
- thermometer.

**Each STUDENT will require:**

- safety glasses
- ***Notebook***

**Things to consider:**

Stress the importance of always undertaking risk assessments before experiments. Students should read the activity's experimental procedures and precautions and check the SDS for all chemicals used.

**Teacher content information:**

Observing chemical changes: a chemical reaction always produces new substances (elements or compounds) which do not return to their original forms unless another chemical reaction occurs. Signs that indicate a chemical reaction has occurred are:

- a new substance is formed
- a gas is emitted (bubbles indicate this)
- a solid (precipitate) forms
- an energy change happens: either the temperature rises (exothermic) or drops (endothermic)
- colour is permanently changed.

**Lesson plan**

**Step 1:** The class brainstorms everyday examples of chemical reactions and how they can be recognised (see *Science by Doing* **Student Guide**).

**Step 2:** Students read experimental procedure and complete a risk assessment. Check all precautions are considered.

**Step 3:** Students complete the experiment in pairs, recording observations in a table.

**Step 4:** Discuss observations made and responses to discussion questions.

**Suggested questions:**

1. What risks can you see in the procedures you will carry out during the experiment?
2. What precautions should you take with the chemicals you are using?
3. What signs of a chemical reaction did you observe when...?

**Follow up:**

Risk assessment procedures should be reemphasised for each subsequent practical activity.

## 2.2 Conservation of mass

**Lesson outcomes**

At the end of this activity students will be able to:

- state the law of conservation of mass in chemical reactions
- write a practical report of an experiment
- distinguish between an hypothesis, a theory and a law in science
- write word equations to represent reactions carried out.

**What ideas might your students already have?**

Students may have a range of ideas about how hypotheses, theories and laws differ.

**Key vocabulary:**

Reactant, product, law, theory.

**Equipment list**

**Each PAIR will require:**

- 100 mL conical flask with stopper
- small test tube
- 0.1M lead nitrate solution
- 0.1M potassium iodide solution
- 10mL measuring cylinder
- electronic or beam balance.

**Each STUDENT will require:**

- safety glasses
- ***Notebook***

**Things to consider:**

**Digital interactive resources:**

**Antoine Lavoisier – Conservation of mass** (4’42’’): This is a dramatic interpretation of Lavoisier’s experiments on conservation of mass in his home laboratory. It stresses his quantitative approach to chemistry and passion for accuracy.

**Law of conservation of mass** (50”): This simulation uses the formation of zinc sulfide to illustrate the law of conservation of mass.

**Teacher content information:**

There is often some confusion between the terms ‘theory’ and ‘law’ in the teaching of science. The view that theories develop into laws is generally not correct.

Most laws that are still recognised today originate from the eighteenth century. They are statements about how certain systems behave, often expressed mathematically. For example the *Law of Constant Proportions* states that in chemical reactions the reactants always react, or combine, in the same proportions. It is a statement of an observed phenomenon that we believe to be consistent.

*Atomic Theory*, on the other hand, is an explanatory model. It explains why chemicals always behave in this way. In biology evolutionary theory provides an explanatory model that accounts for why life on Earth is the way it is. Further evidence will not transform it into Evolutionary Law.

**Lesson plan**

**Step 1:** Begin by discussing what happens to the reactants in a chemical reaction, using the suggestions in the *Science by Doing* **Student Guide** as stimulus material.

**Step 2:** Review report-writing terminology and risk-assessment procedures before starting the practical session.

**Step 3:** Students carry out the practical activity in pairs.

**Step 4:** Discuss the results and work through the word equation example on p18 of the **Student Guide**. The short video simulation, **Law of conservation of mass**, can be used here.

**Step 5:** Students work through the practice equations and write a practical report at their own pace.

**Step 6:** The class watches the video of Lavoisier's experiments and discusses the difference between how scientists of his time worked, compared to how they work today, before completing the ***Notebook*** questions.

**Suggested questions:**

1. What is a hypothesis?
2. What would you include in the method (results, discussion, conclusions) of a practical report?
3. Is this a controlled experiment (fair test)? Explain.
4. What is the difference between a theory and a law in science?

**Follow up:**

Conservation of mass is followed up in the subsequent activities involving formulae and equations. Report writing and risk assessment skills will also be reinforced in many other activities.

## 2.3 Ionic compounds

**Lesson outcomes**

At the end of this activity students will be able to:

- recognise patterns of nuclear structure and valency can be found in the periodic table
- construct models representing the electron configuration of atoms and ions
- use electrical conductivity to distinguish between ionic and covalent substances in solution
- name simple (binary) ionic compounds, given the chemical formula.

**What ideas might your students already have?**

Students should have a basic understanding of the relationship of electron configuration to the periodic table.

**Key vocabulary:**

Ion, ionic bond, valency

**Equipment list**

Modelling atoms and ions

**Each GROUP will require:**

- coloured counters or smarties (as in Activity 1.2).
- *Science by Doing* **Student Digital** - **Build an atom interactive** (**Activity 1.3**).

Memory game

**Each PAIR will require:**

- 20 blank cards.
- distinguishing ionic solutions

**The CLASS will require:**

- one beaker each of liquids labelled A-F: methylated spirits (ethanol), 0.1M sodium chloride, 0.1M potassium iodide, distilled water, 0.1M hydrochloric acid, 0.1M sodium hydroxide.

Each group sets up one solution, with groups rotating about the room to test each.

**Each GROUP will require:**

- power supply (set to 6V)
- electrodes with globe or LED
- beaker of one of the liquids A-F
- tapping key or switch
- 2 electrical leads.

**Each STUDENT will require:**

- safety glasses
- ***Notebook***.

**Things to consider:**

**Models of atoms and ions**: using models is an important step in understanding electron configuration and ion formation.

**Memory game**: assists students to link names and symbols. Works best in pairs.

- Students make pairs of cards with all the formulae shown in the activity on one card and the name of each compound on the other.
- The cards are shuffled and laid face down on the table.
- Taking turns, each student turns up two cards. If the name and formula match, the student claims the pair has another go. If the two cards do not match, they are faced down and another student has a turn.
- Continue until all pairs are matched. The student with the most pairs wins the game.

**Digital interactive resources:**

**Dissociation of salt** (0.53'): Uses atomic models to explain charges involved in dissociation of sodium chloride.

**Salt dissolving in water** (1' 30"): a simulation showing the role of the polar water molecule in splitting NaCl into ions.

**Ionic compounds and their properties** (3'35"): Properties of ionic compounds due to their lattice structure are explained, including dissolving and conductivity when in solution and molten.

**Lesson plan**

**Step 1:** Introduce the concept of why ions form using the imagery and questions in *Science by Doing* **Student Guide**. Students make models with counters (see Part 1).

**Step 2:** Use the **Build the atom** interactive to consolidate.

**Step 3:** Explain the rules for naming ionic compounds (p23 **Student Guide**), giving examples, before students complete questions (below).

**Step 4:** Students make cards and play the memory game (see **Hint**).

**Step 5:** The class completes the practical activity, Distinguishing ionic solutions.

**Step 6:** Class discussion of results and questions, linking to ionic bonds and crystals dissolving to form ions. Use the simulation of salt dissolving in water.

**Suggested questions:**

1. Can you suggest why an atom with one or two outer electrons would lose them easily?
2. What type of element forms positive ions?
3. Can you suggest why an atom with six or seven outer electrons would gain electrons?
4. What type of element forms negative ions?
5. How many chloride ions could $Mg^{2+}$ ($Al^{3+}$ etc) attract?

**Follow up:**

This lesson is a basis for **Activity 2.4**.

## 2.4 Writing chemical formulae

**Lesson outcomes**

At the end of this activity students will be able to:

- recognise that metals donate electrons to non-metals to form ionic compounds
- write formulae of ionic compounds using valency
- recall formulae and valencies for common polyatomic ions.

**What ideas might your students already have?**

Students should have learnt the basics of valency and ion formation in **Activity 2.3**.

**Key vocabulary:**

Polyatomic ion

**Equipment list**

**Each GROUP will require:**

- *Science by Doing* **Student Digital**
- 12 blank memory game cards.

**Each PAIR will require:**

- 20 blank cards.
- distinguishing ionic solutions

**Each STUDENT will require:**

- **Activity sheet 2.4 Ionic formulae**

**Things to consider:**

**Digital interactive resources:**

- Digital Tutorial (2 parts)
- The worksheet includes step-by-step instructions on the cross-over method of writing formulae.
- **Using valency** is an interactive quiz/game to consolidate understanding of writing formulae for ionic compounds.
- **Formulae of Ionic Compounds and their names**: Step by step guide of how to write formulae and name compounds. Part 1 (3'46") deals with diatomic compounds and Part 2 (3'22") polyatomic ions. NB: point out to students not to use upper case letters for formulae names. Also aluminium is Americanised (aluminium).
- **Atomic Bonding Song** (4'49"): This song shows a personification of attraction and sharing involved in ionic and covalent bonding respectively. It is a fun way to revise bonding.

**Lesson plan**

Extension activity: You may decide not to use this activity with the whole class, as the concepts are difficult. However, it could be available for an advanced group.

**Step 1:** Begin by reviewing the formation of ions and introducing the cross-over method of writing formulae, giving examples (see *Science by Doing* **Student Guide**). Students complete the interactive activity in the Digital Guide before working through the examples on the sheet.

**Step 2:** Introduce polyatomic ions and suggest that students add these to their memory game to help associate the formulae with the names.

**Step 3:** Students work through the sheet at their own pace, seeking guidance from the teacher or other students. Have an answer sheet available for individuals to check their progress.

**Step 4:** The Atomic bonding song could be used here as revision.

**Step 5:** The Using valency interactive game/quiz can consolidate or check progress.

**Suggested questions:**

1. What is valency related to?
2. How can you work out if you have the correct formula for a stable compound?

**Follow up:**

Students are encouraged to write formulae for ionic compounds encountered throughout this topic.

## 2.5 Sharing electrons

**Lesson outcomes**

At the end of this activity students will be able to:

- recognise that non-metals react together by forming covalent bonds in which electrons are shared between atoms
- construct models to represent covalent molecules
- correctly name covalent compounds.

**What ideas might your students already have?**

Students should be familiar with the relationship between electron configuration and valency, and the concept that stable compounds form if atoms have a full outer electron shell.

**Key vocabulary:**

Covalent, molecule.

**Equipment list**

**Each GROUP will require:**

- molecular model kit

**Each STUDENT will require:**

- **Activity sheet 2.5 Covalent molecules**
- ***Notebook***

**Lesson plan**

**Step 1:** Introduce molecules and the naming system using *Science by Doing* **Student Guide** stimulus material and questions.

**Step 2:** Students complete **Activity Sheet 2.5 Covalent molecules**. They can check answers with others or with a provided sheet.

**Suggested questions:**

1. Why are electrons shared in covalent molecules?
2. Where do you find elements that form covalent molecules in the periodic table?
3. What do they all have in common?

**Follow up:**

Students are encouraged to name and write formulae for covalent molecules encountered throughout this topic.

## 2.6 It's falling apart

**Lesson outcomes**

At the end of this activity students will be able to:

- describe decomposition reactions as the breaking down of compounds into two or more new substances
- deduce the new substance formed in decomposition reactions
- write word equations to represent decomposition reactions.

**What ideas might your students already have?**

There is often confusion between decomposition and a reaction with oxygen in the air. This must be clarified in the lesson.

**Key vocabulary:**

Decomposition, electrolysis

**Equipment list**

**Teacher demonstration: Electrolysis of water**

**The CLASS will require:**

- Hoffman voltameter
- DC transformer and leads
- 1M sulfuric acid (acidified water)
- 2 test tubes in rack
- 2 splints
- Bunsen burner to light splints

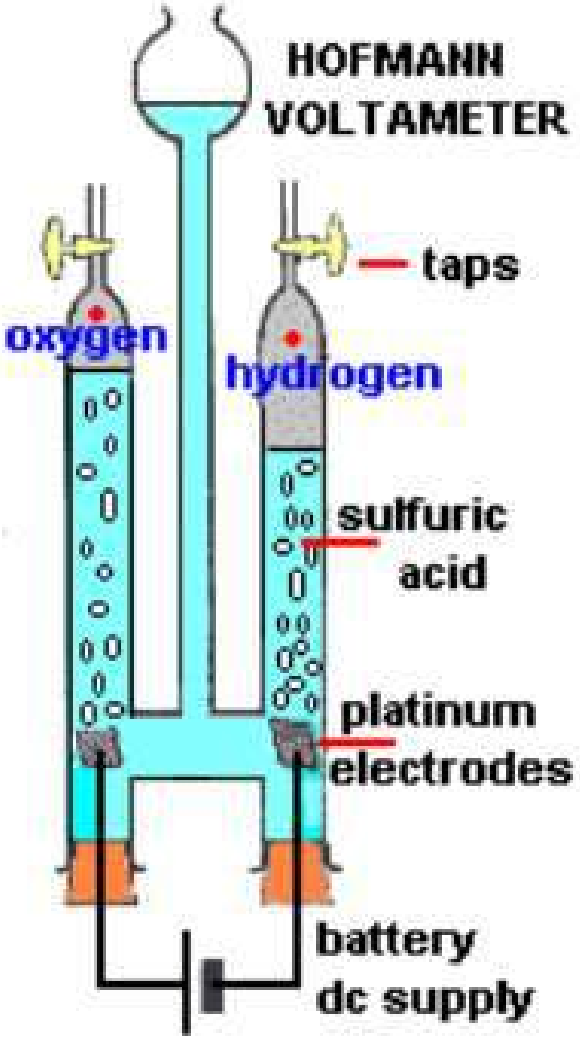
**Class experiment:**

**Each GROUP will require:**

- 2 large test tubes
- stopper with delivery tube
- copper carbonate powder
- spatula
- test-tube rack
- limewater
- Bunsen burner and mat
- retort stand and clamp
- lighter or matches.

**Things to consider:**

**Electrolysis of water**




**Instructions**

**Step 1**: Fill the voltameter with dilute acid, via the reservoir, with taps open until full. Close the taps and connect to power supply. The speed of decomposition can be controlled by regulating the voltage.

**Step 2**: Discuss the process with the class and ask them to predict what will be produced in the decomposition reaction. You may want to start the reaction earlier or finish it later, as before testing the gases it is best to wait until there is at least half a column of hydrogen.

**Step 3**: Students predict which gas is which before you test. The ratio will be 2:1 H:O, as in the $H_2O$ molecule.

**Step 4:** Hydrogen test - hold an inverted test tube over the electrode containing the largest amount of gas. A student lights a splint and holds it near the top of the test tube immediately after it is placed open side up into the rack. The characteristic pop as hydrogen recombines to form water will be heard. Discuss that you have caused another chemical reaction, in which hydrogen has combined with oxygen from the air.

$H_2(g) + O_2(g) \rightarrow H_2O\ (l)$
Look for condensation in the test tube.

**Lesson plan**

**Step 1:** Demonstrate electrolysis of water. While this is reacting discuss what decomposition is and relate it to the reaction occurring in the voltameter.

**Step 2:** Students carry out risk assessments, before doing the Decomposition of copper carbonate experiment.

**Step 3:** Conclude by reviewing the discussion questions, including word equations and formulae.

**Suggested questions:**

1. What is decomposition?
2. What has to happen for a substance to decompose?
3. Where does the energy needed to break the bonds between atoms come from?
4. Can an element/compound decompose? Why or why not?
5. What substances would you expect to be produced when water decomposes?
6. Predict which gas (in voltameter) is which? Explain your choice.
7. Is copper carbonate ionic or covalent? How do you know?

**Follow up:**

**Part 3: Energy and Change** of this unit has more detail on energy changes in reactions.

## 2.7 Reactions in solution

**Lesson outcomes**

At the end of this activity students will be able to:

- define a precipitation reaction as one in which an insoluble solid is produced
- complete and recognise precipitation reactions
- write word equations for precipitation reactions and formulae for reactants and products
- predict the products of precipitation reactions, given solubility rules.

**What ideas might your students already have?**

Students should recognise a precipitate, but may need reminding of the difference between clear and colourless. A coloured but clear solution does not contain a precipitate.

**Key vocabulary:**

Precipitation, cloudy, clear.

**Equipment list**

**Each PAIR will require:**

- Spotting tile or plastic sheet

Dropper bottles of the following 0.1M solutions:

- copper(II) sulfate
- sodium hydroxide
- cobalt(II) chloride
- silver chloride
- sodium carbonate
- barium nitrate

**Each STUDENT will require:**

- safety glasses
- ***Notebook.***

**Things to consider:**

Observations of precipitates: stress precipitation may not occur instantly and students should observe the mixture carefully for swirls of white or colour. These indicate a precipitate has formed.

**Digital interactive resources**

**Precipitation video** (5'): Shows the reaction between sodium chloride and silver nitrate solutions to form a precipitate of silver chloride. The molecules and ions involved are then shown in a simulation of the reaction. (<3 mins)

**Lesson plan**

**Step 1:** Discuss why precipitates form and how they can be recognised (see **Student Guide**).

**Step 2:** Students carry out the **Precipitate reactions** practical in pairs

**Step 3:** Show students the **Precipitation** video and review the practical task, including discussion questions.

**Step 4:** Students use the provided solubility rules to answer the questions in **Making predictions** on p33 **Student Guide**.

**Step 5:** The class could listen to the **Atomic Bonding Song** to review what they have learnt in **Part 2: Reactions happen**.

**Suggested questions:**

1. How do you tell if a precipitate has formed?
2. What happens to the other substances that don't react when mixed?
3. How could we get these out of the solution?
4. If no precipitate forms when you mix two solutions, what is present in the solution that forms?

## 2.8 Reactions revised

### Lesson outcomes

At the end of this activity students will be able to:

- confidently answer questions about atomic structure and bonding.

### Equipment list

**The CLASS will require:**

- Cards for headbands (See **Activity 1.1** for details of game)

Label suggestions are: nitrogen molecule ($N_2$), hydrogen molecule ($H_2$), magnesium, zinc, iodine, neon, water, sulfuric acid ($H_2SO_4$), carbonate ion ($CO_3^{2-}$), chloride ion ($Cl^-$), hydroxide ion ($OH^-$), potassium ion ($K^+$).

### Lesson plan

**Step 1:** Start the lesson by giving the class 10 minutes to revise using memory cards (or set as homework the previous lesson).

**Step 2:** Play **Celebrity Chemistry Hats**, clarifying any issues as the game proceeds.

**Follow up:**

Note any misunderstandings for emphasis in subsequent lessons.