Government of **Western Australia**
School Curriculum and Standards Authority

Science: Chemical sciences

Teaching, learning and assessment exemplar

Year 7

States of matter and particles

Acknowledgement of Country

Kaya. The School Curriculum and Standards Authority (the Authority) acknowledges that our offices are on Whadjuk Noongar boodjar and that we deliver our services on the country of many traditional custodians and language groups throughout Western Australia. The Authority acknowledges the traditional custodians throughout Western Australia and their continuing connection to land, waters and community. We offer our respect to Elders past and present.

Background

This teaching, learning and assessment exemplar (the exemplar) has been developed by the School Curriculum and Standards Authority (the Authority) as part of the *School Education Act Employees (Teachers and Administrators) General Agreement 2017* (Clause 61.1–61.3).

2025/24041[v5]

Contents

The Western Australian Curriculum

The *Western Australian Curriculum and Assessment Outline* (the *Outline* – https://k10outline.scsa.wa.edu.au/) sets out the mandated curriculum, guiding principles for teaching, learning and assessment, and support for teachers in their assessment and reporting of student achievement. The *Outline* recognises that all students in Australian schools, or international schools implementing the Western Australian Curriculum, are entitled to be given access to the eight learning areas described in the *Alice Springs* (*Mparntwe*) *Education Declaration*, December 2019.

The Science curriculum

The mandated curriculum is presented in the year level syllabus documents.

The Science curriculum delivers a sequential and age-appropriate progression of learning with the following key elements:

- a year level description that provides an overview of the context for teaching and learning in the year
- a series of content descriptions, populated through strands and sub-strands, that sets out the knowledge, understanding and skills that teachers are expected to teach and students are expected to learn
- an achievement standard that describes an expected level that the majority of students are achieving by the end of a given year of schooling. An achievement standard describes the quality of learning (e.g. the depth of conceptual understanding and the sophistication of skills) that would indicate the student is well placed to commence the learning required in the next year.

This exemplar

This Science exemplar articulates the content in the *Outline* and approaches to teaching, learning and assessment reflective of the Principles of Teaching, Learning and Assessment. This exemplar demonstrates a sequence of teaching and learning, including suggested assessment points, for 12 lessons.

Catering for diversity

This exemplar provides a suggested approach for the delivery of the curriculum and reflects the rationale, aims and content structure of the learning area. When planning the learning experiences, consideration has been given to ensuring that they are inclusive and can be used in, or adapted for, individual circumstances. It is the classroom teacher who is best placed to consider and respond to (accommodate) the diversity of their students. Reflecting on the learning experiences offered in this exemplar will enable teachers to make appropriate adjustments (where applicable) to better cater for students' gender, personal interests, achievement levels, socio-economic, cultural and language backgrounds, experiences and local area contexts.

Safety

Science learning experiences may involve the use of potentially hazardous substances and/or hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the *Work Health and Safety Act 2011*, in addition to relevant State health and safety guidelines.

Using this exemplar

This teaching, learning and assessment exemplar provides suggestions to support the delivery of the mandated curriculum content. The exemplar provides:

- a teaching and learning sequence
- the mandated curriculum content to be taught at each point of the teaching and learning sequence, suggested resources, a sample assessment task and marking key
- the number of lessons to deliver the teaching and learning experiences
- learning intentions and support notes that may provide focus questions and additional information and/or examples to assist with the interpretation of curriculum content
- support notes to assist teachers to unpack the content and support teaching and learning experiences
- teaching and learning experiences that outline the structure of the lesson. These explicitly state each activity that the lesson will progress through and the key focus area for that activity.

Links to electronic resources

This sequence of lessons may utilise electronic web-based resources, such as videos and image galleries. Teachers should be present while an electronic resource is in use and close links immediately after a resource, such as a video, has played to prevent default 'auto play' of additional videos. Where resources are referred for home study, they should be uploaded through Connect, or an equivalent system, that filters advertising content.

Best practice

Teaching and learning

The teaching and learning opportunities offered in this exemplar are not exhaustive. Thus, teachers are encouraged to make professional decisions about which learning experiences, and the sequence in which they are delivered, are best suited to their classroom context, taking into account the availability of resources and student ability.

This sample may prove a useful starting point for amplifying creativity in the classroom, while presenting the embedded expectations of the Western Australian Curriculum: Science.

Teachers may find opportunities to incorporate the General Capabilities and the Cross-curriculum Priorities into the teaching and learning program.

Ways of teaching – teachers can locate additional information on the Ways of teaching from the School Curriculum and Standards Authority (the Authority) website https://k10outline.scsa.wa.edu.au/home/wa-curriculum/learning-areas/science/overview/science-ways-of-teaching.

Assessing

Assessment, both formative and summative, is an integral part of teaching and learning. Assessment should arise naturally out of the learning experiences provided to students. In addition, assessment should provide regular opportunities for teachers to reflect on student achievement and progress. As part of the support it provides for teachers, this exemplar includes suggested assessment points. It is the teacher’s role to consider the contexts of their classroom and students, the range of assessments required, and the sampling of content descriptions selected to allow their students the opportunity to demonstrate achievement in relation to the year level achievement standard. Teachers are best placed to make decisions about whether the suggested assessment/s are used as formative or summative assessment and/or for moderation purposes.

Ways of assessing – a range of assessment strategies that can enable teachers to understand where students are in their learning is available on the Authority website https://k10outline.scsa.wa.edu.au/home/teaching/curriculum-browser/science-v8/overview/ways-of-assessing.

Reflecting

Reflective practice involves a cyclic process during which teachers continually review the effects of their teaching and make appropriate adjustments to their planning. The cycle involves planning, teaching, observing, reflecting and replanning.

This exemplar supports reflective practice and provides flexibility for teachers in their planning. The exemplar shows how content can be combined and revisited throughout the year. Teachers will choose to expand or contract the amount of time spent on developing the required understandings and skills according to their reflective processes and professional judgements about their students’ evolving learning needs.

States of matter and particles

This teaching and learning sequence will develop students' understanding of how the properties of the states of matter can be explained in terms of the particle model and states can change with the addition or removal of energy. In addition to explicit teaching, students are provided opportunities to engage and explore the physical properties of solids, liquids and gases.

The teaching and learning sequence enables students to develop knowledge and skills to apply their understanding of the changes of state and the particle model. Students will apply this understanding by explaining observations in terms of the changes in kinetic and potential energy. This prepares them to confidently apply their understanding in the summative assessment.

Year level description

In the early adolescence phase of schooling, students align with their peer group and begin to question established conventions, practices and values. Teaching and learning programs assist students to develop a broader and more comprehensive understanding of the contexts of their lives and the world in which they live.

Science provides opportunities for students to continue developing their understanding of important concepts and making connections between different areas of science and applications observed in their daily life.

In Year 7, students explore the diversity of life on Earth and continue to develop their understanding of the role of classification in ordering and organising information. They use and develop models, such as food chains and food webs, to represent energy flow in ecosystems and predict impacts of human activity. They use the particle theory to explain the motion and arrangement of atoms and molecules in the different states of matter and select appropriate techniques to separate pure substances from mixtures. They explore different types of celestial objects, investigate relationships in the Earth-Sun-Moon system and use models to predict and explain events. They consider the impact of forces acting on objects, represent and predict the effects of unbalanced forces on motion and determine the type of mechanical advantage provided by simple machines.

Students propose questions and make predictions based on scientific knowledge. They recognise risks when planning and conducting reproducible investigations. Students construct appropriate representations to organise and process data. They analyse data to describe patterns and relationships and use evidence to support conclusions. Students identify possible sources of error in their methods and suggest improvements. They use appropriate language and text features for their purpose and audience when communicating their ideas and findings. Students examine situations where development of scientific knowledge has benefited from collaboration and influenced the development of human activity.

Achievement standard

By the end of the year:

Students use classification tools to classify and group organisms based on observable features. They represent the flow of energy in ecosystems and predict the impacts of human activity. They describe the motion and arrangement of atoms and molecules in solids, liquids and gases and describe techniques to separate pure substances in a mixture. They can classify celestial objects based on their observable properties and describe how the relative positions of Earth, the Sun and Moon affect phenomena on Earth. They can identify situations when friction, gravitational, magnetic and electrostatic forces are acting, represent and predict the effects of unbalanced forces on motion and identify the type of mechanical advantage provided by simple machines.

Students plan and conduct reproducible investigations to test relationships and aspects of scientific models. They identify risks involved in conducting investigations. They use equipment to generate and record data with precision. They construct appropriate representations to organise data and information. They analyse data and information to describe patterns and relationships. They identify possible sources of error in methods and suggest improvements to their methods. They identify evidence to support their conclusions and support or dispute claims. They select and use language and text features appropriately for their purpose and audience when communicating their ideas and findings. They identify situations where development of scientific knowledge has benefited from collaboration and has influenced the development of human activity.

Lessons 1–12

States of matter and particles

Lesson 1: Properties of solids, liquids and gases

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information
- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Resources

- Activity 1: Properties of solids, liquids and gases (Appendix B)
- Veritasium – States of Matter
  https://www.youtube.com/watch?v=KCL8zqjXbME

Teacher information

- This is an introductory lesson to allow students to recall prior knowledge and to use observational skills to develop a set of common characteristics for the states of matter.

Lesson outline

Learning intentions
Students will: • recall the three states of matter as solid, liquid and gas • describe the general physical properties of solids, liquids and gases in terms of shape, volume and compressibility • recognise that there are other states of matter in addition to solids, liquids and gases.

Introduction

- Complete a brainstorm activity to elicit prior knowledge based on the following focus questions:
  - What do you know about solids, liquids and gases? What is matter?
  - How do you decide if something is a solid, liquid or gas?

Lesson activities

Activity 1

- Demonstrate and explain the procedure for Activity 1 and the safety procedures to be followed.
- Instruct students to complete Activity 1: Properties of solids, liquids and gases (Appendix B). This is a rotating stations or group activity where students move between different stations, record their observations of solids, liquids and gases in the table provided, and develop a set of common characteristics for the three states of matter.
- Discuss the student observations from the activity and review the properties of the three main states of matter.

Activity 2

- Explicitly teach the following:
  - the three states of matter as solid, liquid and gas
  - how to describe the general physical properties of solids, liquids and gases in terms of shape, volume and compressibility
  - that there are other states of matter in addition to solids, liquids and gases.
- Instruct students to take notes and draw diagrams on the presented information.

Concluding activity

- Provide students with a glossary sheet with a list of terms (Appendix B), or have students start their own glossary to record the definitions they encounter throughout the unit.

Optional activity

- Students use online resources to research the states of matter beyond solids, liquids and gases.

Lesson 2: Brownian motion and the particle model

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information
- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Resources

- Activity 2: Brownian motion and the particle model (Appendix B)
- Johnstone's model of the macroscopic, submicroscopic and symbolic to support the development of students' understanding of the link between the macroscopic (observable properties) and the submicroscopic (particle) levels. For guidance on this model, see:
  Rachael Hofgartner for the Royal Society of Chemistry: Education in chemistry – Develop deeper understanding with models
  https://edu.rsc.org/feature/develop-deeper-understanding-with-models/3010519.article

Teacher information

- Kinetic energy – the energy of the movement of particles.
- Potential energy – the energy associated with the distance between particles.
- Temperature – a measure of the average kinetic energy of particles in a system.
- Brownian motion – In 1827, Robert Brown observed that pollen grains, when suspended in water, would move in random, irregular patterns. This random movement of particles was named 'Brownian motion'.
- In 1905, Albert Einstein submitted a paper to a journal in which he explained that Brownian motion was due to the collisions between the pollen grains and invisible particles (atoms). At this point, the existence of atoms was not universally accepted. While the paper produced in 1905 provided a theoretical framework within which to view Brownian motion, Einstein, in a later paper, suggested an experimental way to test his theory.
- Experimental work carried out by Jean Perrin in 1908 supported the theory developed by Einstein and led to broad acceptance of the atomic theory.

(Dot points 4–6 information from: American Physical Society, 2005).

Lesson outline

Learning intentions
Students will: • describe the particle model of matter • use the particle model to explain the physical properties of matter, including: ▪ shape ▪ volume ▪ compressibility • describe Brownian motion • explain how Brownian motion can be used to justify the particle model.

Introduction

- Conduct a class discussion to consider the following focus question: Why is the particle model a better representation of matter?
- Use students' answers to lead into Activity 2.

Lesson activities

Activity 1

- Explicitly teach the following:
  - particle model i.e. that matter is made up of small particles, and that the movement and arrangement of particles can be used to explain many of the physical properties of matter
  - historical context for the particle model.
- Instruct students to take notes and draw diagrams on the presented information.

Activity 2

- Demonstrate and explain the procedure for Activity 1 and the safety procedures to be followed.
- Instruct students to complete Activity 2: Brownian motion and the particle model (Appendix B). Students observe the movement of fat globules in milk.
- Through discussion and questioning, guide students to the understanding that the movement is explained by the collisions between the fat and other particles in the milk that are too small to be seen.
- Use Johnstone's model of the macroscopic, submicroscopic and symbolic to support the development of students' understanding of the link between the macroscopic (observable properties) and the submicroscopic (particle) levels.

Concluding activity

- Students complete a worksheet showing the link between the particle model and the states of matter (Appendix B).
- Discuss and review students' answers to the questions in the worksheet.

Lesson 3: Can gases be poured?

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Questioning and predicting

- Propose investigable questions and make predictions based on scientific knowledge to explore scientific models, identify patterns and test relationships

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information
- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Resources

- Activity 3: Can gases be poured? (Appendix B)
- katalyst812 – Displacement of water method to collect gas
  https://www.youtube.com/watch?v=Ol-2JN01Cfo

Teacher information

- This lesson allows students to recall prior knowledge and use observational skills to further develop their understanding of the common characteristics for the states of matter.
- The experiment in Activity 3 could be conducted as a student activity or a teacher demonstration.
- Dry ice could be used to complete this activity instead of using the experiment in the Activity 3 task sheet.

Lesson outline

Learning intentions

Students will:
• describe the general physical properties of solids, liquids and gases in terms of:
  ▪ shape
  ▪ volume
  ▪ compressibility
• use the particle model to explain the physical properties of matter, including:
  ▪ shape
  ▪ volume
  ▪ compressibility.

Introduction

- Conduct a class discussion to consider the following focus question: Can gases, like liquids, be poured?
- Use students' answers to lead into Activity 3.

Lesson activities

Activity 1

- Demonstrate and explain the procedure for Activity 1 and the safety procedures to be followed.
- Instruct students to complete Activity 3: Can gases be poured? (Appendix B).
  In this activity, students will see that gases, like liquids, can be poured. Carbon dioxide is used as it is denser than air. Introduce the concept of density to explain why carbon dioxide can be poured (density will be addressed more explicitly in Activity 6).

Activity 2

- Once students have completed Activity 3, discuss any observations and answers to the questions on the task sheet for the activity.
- Summarise with the class the common physical properties of solids, liquids and gases. Reinforce how the particle model can be used to explain these observations.
- Students should update the definitions in the glossary (Appendix B) provided during Lesson 1 if time permits.

Concluding activity

- Conduct an activity in which students identify two things they have learnt during the lesson and one question. Discuss these in groups or as a class.

Lesson 4: Diffusion

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Resources

- Activity 4: Diffusion (Appendix B)
- Science Garage – Potassium Permanganate Diffusion (Time Lapse) https://www.youtube.com/watch?v=55CPfc9ij48
- PhET and University of Colorado Boulder – Diffusion https://phet.colorado.edu/en/simulations/diffusion

Teacher information

- This lesson allows students to recall prior knowledge and use observational skills to further develop their understanding of the common characteristics for the states of matter.
- Diffusion occurs when one substance is added to a fluid (liquid or gas), and the particles of that substance spread throughout the fluid due to the movement of particles.

Lesson outline

Learning intention
Students will: • describe and explain, in terms of the particle model, the physical properties of solids, liquids and gases for diffusion.

Introduction

- Brainstorm the following focus questions to elicit students' prior knowledge:
  - Why can we smell perfume when standing a distance away from someone?
  - What happens when a solid dissolves in water?
- Use students' answers to lead into Activity 4.

Lesson activities

Activity 1

- Demonstrate and explain the procedure for Activity 4 and the safety procedures to be followed.
- Instruct students to complete Activity 4: Diffusion (Appendix B).
  During this activity, the teacher will demonstrate diffusion in liquids and gases. Students will develop an understanding of diffusion and how it is explained using the particle model.
  Note: Be aware of any allergies or reactions students may have to perfumes/room sprays before conducting this demonstration.
- Once students have completed Activity 4, discuss any observations and answers to the questions on the activity's task sheet.
- Summarise with the class the common physical properties of solids, liquids and gases. Reinforce how the particle model can be used to explain these observations.

Activity 2

- Explicitly teach the concept of diffusion in terms of the particle model.
- Instruct students to take notes and draw diagrams on the presented information.

Concluding activity

- Students are to write the definition of diffusion in their glossary.

Lesson 5: Gas pressure

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Resources

- Activity 5: Gas pressure (Appendix B)
- PhET and University of Colorado Boulder – Gases Intro https://phet.colorado.edu/sims/html/gases-intro/latest/gases-intro_en.html

Teacher information

- This lesson allows students to recall prior knowledge and use observational skills to further develop their understanding of the common characteristics for the states of matter.
- Gas pressure is a measure of the collisions of particles with the walls of a container per unit time. Gas pressure is independent of the mass of a gas particle but is dependent on the number of particles present (as well as temperature and volume).

Lesson outline

Learning intention
Students will: • describe and explain, in terms of the particle model, the physical properties of gases for pressure.

Introduction

- Brainstorm prior knowledge of gas pressure and where students may have encountered it around the home; for example, pumping up their bike tyres.
- Use students' answers to lead into Activity 5.

Lesson activities

Activity 1

- Demonstrate and explain the procedure for Activity 5 and the safety procedures to be followed.
- Instruct students to complete Activity 5: Gas pressure (Appendix B).
  During this activity, students use balloons to develop an understanding (at the macroscopic level) that gas has mass and takes up space. By blowing up the balloons, students will observe what happens when gas is added to a system.
- Use available simulations to develop an understanding (at the microscopic level) of how the particle model can be used to explain the relationships between gas pressure and the number of particles, volume and temperature.
- Once students have completed Activity 5, discuss any observations and answers to the questions on the task sheet.
- Reinforce how the particle model can be used to explain these observations.

Activity 2

- Explicitly teach the concept of gas pressure in terms of the particle model.
- Instruct students to take notes and draw diagrams on the presented information.

Concluding activity

- Summarise, in discussion with students, the outcomes of Activity 5. Students update their glossaries with any new terms.

Lessons 6–7: Density

The Western Australian Curriculum content addressed in these lessons is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information
- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Communicating

- Communicate ideas, findings and information for specific purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate

Resources

- Activity 6: Density (Appendix B)
- MythBusters – How Many Balloons to Lift a Child?
  https://www.youtube.com/watch?v=bCjf9TAaNJA
- MWSU Chemistry Department – Demonstrating Gas Density
  https://www.youtube.com/watch?v=aubbTamE71Q

Teacher information

Note: Two lessons have been allocated to this topic as students may require more time to complete the suggested activity. Additional activities have been suggested to complement the activity.

- This lesson allows students to recall prior knowledge and use observational skills to further develop their understanding of the common characteristics for the states of matter.
- Density, which is a measure of the mass of a substance per unit volume (the students will be using g/cm^3), can be explained through the particle model by the packing of the particles and their mass. When comparing the same substance in different states, the distance between the particles has the greatest effect on the density.
- Water is a very rare substance because its density in the solid state is less than the liquid state.

Lesson outline

Learning intention
Students will: • describe and explain, in terms of the particle model, the physical properties of solids, liquids and gases for density.

Introduction

- Conduct a class discussion in which students recall from Activity 2 that carbon dioxide could be poured as it was heavier (denser) than air.
- Demonstrate that gases can have different densities by providing examples of hydrogen or helium, nitrogen and carbon dioxide in balloons, and discussing with students how they float or sink in the air.
- Where access to gases such as helium or hydrogen is not possible, choose online examples to illustrate that they are less dense than air.
- Online examples of density in solids, liquids and gases could also be shown.

Lesson activities

Activity 1

- Explicitly teach the following concepts:
  - density
  - how density is calculated.
- Instruct students to take notes and draw diagrams on the presented information on the first part of the Activity 6 task sheet.

Activity 2

- Demonstrate and explain the procedure for Activity 6 and the safety procedures to be followed.
- Instruct students to complete Activity 6: Density (Appendix B).
  Students compare the density of a range of solids, liquids and gases to develop an understanding of the concept.

Concluding activity

- Discuss the results obtained by the students from the activity and identify which substance was the densest, least dense and any other unexpected results.

Optional activities

- Research activity – Ice is less dense than water. Why is this important? Students, in groups, research the question and provide a three-minute oral presentation that is peer reviewed.
- Students could investigate how many five-cent pieces it takes to sink a boat made from one sheet of A4 paper.

Lesson 8: Review of the states of matter

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Resource

- Investigate the use of a suitable graphic organiser for students to produce a visual summary of the concepts covered in Lessons 1–7. Examples could include mind mapping or fishbone graphic organisers.

Teacher information

- In this lesson, students will have the opportunity to consolidate their understanding of the properties of solids, liquids and gases.

Lesson outline

Learning intentions
Students will: • recall the three states of matter as solid, liquid and gas • use the particle model to explain the physical properties of matter, including: ▪ shape ▪ volume ▪ compressibility • recognise that there are other states of matter in addition to solids, liquids and gases • describe Brownian motion • explain how Brownian motion can be used to justify the particle model • describe and explain, in terms of the particle model, the physical properties of solids, liquids and gases for: ▪ diffusion ▪ pressure (gases only) ▪ density.

Introduction

- Review students' understanding of the particle model and the properties of the different states of matter by using either a paper or online quiz.

Lesson activities

Activity 1

- Instruct students to use a suitable graphic organiser to produce a visual summary of the concepts covered in Lessons 1–7. Examples could include, but are not limited to, mind mapping or fishbone graphic organisers.

Concluding activity

- Students are to pair up and share their work with each other.

Optional activity

- Create a digital animation, movie, infographic or any suitable method of presentation. The model/representation should include an explanation of the particle model and the properties of the different states of matter.

Lessons 9–10: Heating water

The Western Australian Curriculum content addressed in these lessons is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Questioning and predicting

- Propose investigable questions and make predictions based on scientific knowledge to explore scientific models, identify patterns and test relationships

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information
- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Evaluating

- Construct evidence-based arguments to support conclusions or evaluate claims

Resource

- Activity 7: Heating water (Appendix B)

Teacher information

Note: Two lessons have been allocated to this topic as students may require more time to complete the suggested activity.

- Boiling is a change of state from liquid to gas that occurs at a single temperature (for a given pressure) for a pure substance. Bubbles of the gaseous state of the substance form throughout the liquid state.
- Evaporation is the change of state of a substance from liquid to gas that occurs at any temperature and at the surface only.
- During a change of state at the melting and boiling points, the temperature remains constant, as the heat energy going into the system is transformed into potential energy and the kinetic energy of the particles remains constant.
- Between a change of state, most of the heat energy going into the system is transformed into kinetic energy. For solids and liquids, there is a small (could be considered negligible) increase in potential energy. For gases, there is a more significant increase in potential energy. This is

justified by the fact that solids and liquids expand slightly on heating, but gases expand significantly on heating.

- Kinetic energy – the energy of the movement of particles.
- Potential energy – the energy associated with the distance between particles.
- Temperature – a measure of the average kinetic energy of particles in a system.

Lesson outline

Learning intentions

Students will:
• describe a substance as it changes state from solid to liquid to gas
• draw and label a change of state diagram
• define the term:
  ▪ melting
  ▪ boiling
  ▪ condensation
  ▪ freezing
  ▪ solidifying
  ▪ evaporation
  ▪ kinetic energy
  ▪ potential energy
  ▪ temperature
• explain, with the use of a graph, how kinetic and potential energies change as a pure substance is heated or cooled
• represent the changes of state diagrammatically, using the particle model.

Introduction

- Brainstorm the following focus questions to elicit students' prior knowledge:
  - What happens when we heat ice?
  - How does the temperature change while we are heating?
- Use students' answers to lead into the next activity.

Lesson activities

Activity 1

- Explicitly teach the following:
  - the concepts of kinetic and potential energy (or revise the concepts, if they have already been introduced through a Physical sciences unit)
  - define the terms:
    - melting
    - boiling
    - condensation
    - freezing
    - solidifying
    - evaporation
  - how kinetic and potential energies change as a pure substance is heated or cooled
  - changes of state can be represented diagrammatically and explained using the particle model.
- Instruct students to take notes and draw diagrams on the presented information.

Activity 2

- Demonstrate and explain the procedure for Activity 7 and the safety procedures to be followed.
- Instruct students to complete Activity 7: Heating water (Appendix B).

In this activity, students will measure temperature as they heat ice through to boiling and then graph the results. Conduct this activity as a predict-observe-explain (POE). Students predict what will happen to the temperature as they heat ice through to boiling. They observe the temperature change and then explain the data obtained.

Activity 3

- On completion of Activity 7, discuss which parts of the students' graphs represent an increase in kinetic energy and which parts represent an increase in potential energy. Students annotate their graphs with this information.
- Introduce the 'change of state' triangle and define each of the changes of state.
- Summarise the difference between boiling point and evaporation for students.
- Instruct students to record this information on the task sheet for Activity 7 or in their notes.

Concluding activity

- Review students' understanding of the content covered in the lessons regarding changes of state by using a paper or online quiz.

Lesson 11: Sublimation and deposition

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Planning and conducting

- Select and use equipment to generate and record data with precision, using digital tools as appropriate

Processing, modelling and analysing

- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Evaluating

- Construct evidence-based arguments to support conclusions or evaluate claims

---

Resources

- Activity 8: Sublimation of dry ice (Appendix B)
- MrLundScience – Sublimation And Deposition (Chemistry Demonstration) https://www.youtube.com/watch?v=YH2Lfc1KLQE
- Chillistick – How To Make The Perfect Fog Effect Using Dry Ice! https://www.youtube.com/watch?v=BsO1B-FWD6I
- PhET and University of Colorado Boulder – States of Matter: Basics https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html

Teacher information

- Sublimation refers to a substance changing directly from a solid to a gas without becoming liquid.
- Deposition refers to a substance changing directly from a gas to a solid without becoming liquid.

Lesson outline

Learning intentions

Students will:
• describe a substance as it changes state from solid to liquid to gas
• draw and label a change of state diagram
• define the terms:
  ▪ sublimation
  ▪ deposition.

Introduction

- Use the think-pair-share strategy to answer the following questions:
  - What is meant by the term ‘phase change’?
  - How can you make a substance change phase?
- Introduce the idea that not all substances will undergo the phase changes (solid, liquid and gas) like water. Use this concept to lead into Activity 8.

Lesson activities

Activity 1

- Demonstrate and explain the procedure for Activity 8 and the safety procedures to be followed.
- Instruct students to complete Activity 8: Sublimation of dry ice (Appendix B).
  In this activity, students will observe sublimation and explain the change of state using the particle model.
- Discuss the students’ observations and their written responses from the task sheet.
- Use students’ answers to lead into the explicit teaching of the concepts.

Activity 2

- Explicitly teach the following:
  - define the terms:
    - sublimation
    - deposition
  - changes of state can be explained using the particle model.
- Instruct students to take notes and draw diagrams on the presented information.

Concluding activity

- Instruct students to update their glossaries to incorporate the terminology taught during the last three lessons.

Optional activity

- Investigate the ‘Phase Changes’ tab of the *PhET – States of matter: Basics* webpage, which looks at the effect of factors other than temperature on changes of state.

Lesson 12: Summative assessment

The Western Australian Curriculum content addressed in this lesson is below.

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Processing, modelling and analysing

- Construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information
- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Evaluating

- Construct evidence-based arguments to support conclusions or evaluate claims

Communicating

- Communicate ideas, findings and information for specific purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate

Resource

- Appendix A: Assessment task
- Graph paper

Teacher information

- Students work independently, under test conditions, for one 50-minute lesson.

Lesson outline

Learning intentions
Students will: • describe and explain the concepts related to the particle model and changes of state from solid to liquid to gas • define and apply the following terms: ▪ melting ▪ boiling ▪ condensation ▪ freezing ▪ solidifying ▪ evaporation ▪ kinetic energy ▪ potential energy ▪ temperature • explain, with the use of a graph, how kinetic and potential energies change as a pure substance is heated or cooled • represent the changes of state diagrammatically, using the particle model.

Introduction

- Follow the instructions provided in the assessment task in Appendix A.

Lesson activities

Activity

- Students complete the assessment task individually, under test conditions.

Appendix A

Assessment task

Change of state graphical analysis

Task details

Title	Change of state graphical analysis
Description	Students graph the temperature changes over time provided for the heating of a pure substance and explain the graph in terms of changes in kinetic and potential energy.
Type of assessment	Summative
Ways of assessing	Graphing and questions
Evidence to be collected	Student assessment sheet
Suggested time	One 50-minute lesson
Differentiation	Teachers should differentiate their teaching and assessment to meet the specific learning needs of their students, based on their level of readiness to learn and their need to be challenged. Where appropriate, teachers may either scaffold or extend the scope of the assessment tasks.

Content descriptions

Science understanding

Chemical sciences

- Properties of the different states of matter can be explained by the motion and arrangement of atoms and molecules (particles); states can change with the addition or removal of energy

Science inquiry

Processing, modelling and analysing

- Construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information
- Analyse data and information to describe patterns and relationships, identify anomalies and draw conclusions based on evidence

Evaluating

- Construct evidence-based arguments to support conclusions or evaluate claims

Communicating

- Communicate ideas, findings and information for specific purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate

Key concepts

Properties of the different states of matter; The particle model; Graphing skills

Information for teachers

In this activity, students will apply their knowledge and understanding of the change of state process by graphing a set of given data and explaining the shape of the curve in terms of the changes in kinetic and potential energy.

Students will work independently, under test conditions, in one 50-minute lesson.

Task sheet: Change of state graphical analysis

A student was given 100.0 g of ethanol at 120 °C and cooled the sample from gas through to solid and obtained the following data.

Time (min)	Temp (°C)
0	120
1	100
2	78
3	78
4	78
5	78
6	78
7	78
8	78
9	78
10	78
11	78
12	78
13	78
14	64
15	50
16	37

Time (min)	Temp (°C)
17	25
18	12
19	0
20	−15
21	−33
22	−45
23	−57
24	−67
25	−80
26	−92
27	−105
28	−114
29	−114
30	−126
31	−138
32	−150

1. Draw a fully labelled graph from the data above on the paper provided. (8 marks)
2. Describe the changes in kinetic and potential energy between the following times.

Time (min)	Change in kinetic energy	Change in potential energy
0–2		
2–13		
13–28		
28–29		
29–32		

(5 marks)

3. Explain why the time taken to change from gas to liquid is much longer than the time taken to change from liquid to solid. (4 marks)

____

____

____

____

____

____

____

4. Draw diagrams representing the particles at the following temperatures. (6 marks)

Temperature (°C)	**Particle diagram**
100	
15	
−130	

5. Explain the difference between evaporation and boiling. (6 marks)

____

____

____

____

____

____

Marking key

Description	Marks
Question 1	
Provides an appropriate title	1
Correctly labels axes, including appropriate units	1–2
Uses an appropriate scale	1
Correctly plots points	1
Draws a line graph	1
Clearly showing changes of state	1–2
Subtotal	**/8**
Question 2	
Changes in kinetic and potential energy correctly identified	1–5
Subtotal	**/5**

Time (min)	Change in kinetic energy	Change in potential energy
0–2	Increasing	No change
2–13	No change	Increasing
13–28	Increasing	Either no change or very slight increase
28–29	No change	Increasing
29–32	Increasing	Increasing

Question 3	
• Distance between the particles in the gas is much greater than the distance between the particles in the liquid. • Distance between the particles in the liquid is similar to the distance between the particles in the solid. • The decrease in potential energy during the change of state from gas to liquid is therefore much greater than the decrease in potential energy during the change of state from liquid to solid. • Therefore, much more energy must be removed from the system during the change of state from gas to liquid, which will therefore take longer.	1–4
Subtotal	**/4**

Description	Marks
Question 4	
For 100 °C, the diagram should show • large distances between particles • few particles present	1–2
For 15 °C, the diagram should show • particles tightly packed • irregular arrangement	1–2
For −130 °C, the diagram should show • particles tightly packed • regular arrangement	1–2
Subtotal	**/6**
Question 5	
Comprehensively contrasts the two processes	5–6
Is unable to provide a contrast for each difference	1–4
• Boiling occurs throughout a liquid. • Evaporation occurs only at the surface. • The temperature remains constant during boiling. • Evaporation occurs at a range of temperatures. • Boiling is a faster change of state than evaporation.	
Subtotal	**/6**
Total	**/29**

Appendix B

Resources

Glossary – States of matter and particles

Complete this glossary as you encounter each of the terms below. There is space at the end for you to add additional terms and their definitions.

Term	Definition
boiling	
brittle	
compound	
condensation	
density	
deposition	
diffusion	
ductile	
element	
evaporation	
freezing	
hardness	
kinetic energy	
lustre	
malleable	
melting	
molecule	
network/lattice	
potential energy	
pressure (gas)	
solidifying	

Term	Definition
sublimation	
temperature	

Activity 1: Properties of solids, liquids and gases

In this activity, students will review the common physical properties of solids, liquids and gases by observing a number of substances.

Instructions for teachers

This activity is designed to be run as a rotating stations activity but can be done as a group activity if there are sufficient materials available.

Move students in groups between the stations, setting a time limit for each station.

With students, review their summaries at the end of the activity.

Materials

- examples of solids:
  - block of wood
  - non-metal, such as sulfur, graphite
  - metal, such as zinc, copper, iron
- examples of liquids in beakers:
  - water
  - methylated spirits
  - mercury (in sealed jar – students not to pick up)
- examples of gases:
  - air in a sealed syringe
  - coloured gas, such as nitrogen dioxide (for teacher demonstration only)
- additional beakers for each liquid other than mercury
- additional plastic syringes for each liquid other than mercury (to test for compressibility)
- Task sheet: Properties of solids, liquids and gases

Instructions to students

- Examine each of the substances and make observations about shape, volume, compressibility and colour.
- Produce a summary of the common physical properties of solids, liquids and gases.

Task sheet: Properties of solids, liquids and gases

What are the general properties of solids, liquids and gases?

Instructions

- For each substance, record your observations.
- Where appropriate, transfer the substance from one beaker to another, by pouring.
- Where appropriate, transfer the substance to a syringe, and attempt to reduce its volume.
- Use the following terms for:
  - shape –
    - fixed
    - variable
  - volume –
    - fixed
    - variable
  - compressibility –
    - yes
    - no
  - colour –
    - provide the colour
    - describe as colourless.

Observations

Substance	Shape	Volume	Compressibility	Colour

Processing of results

Complete the following table.

State	Shape	Volume	Compressibility
solid			
liquid			
gas			

Why do you think colour was not included in this summary table?

____

____

____

____

____

Summarise what you knew before this activity and what you have learnt from the activity.

____

____

____

____

____

____

____

____

____

____

Activity 2: Brownian motion and the particle model

In this activity, students will observe Brownian motion in a dilute milk solution.

Prior knowledge
It is expected that students know how to prepare a wet mount slide and use a microscope.

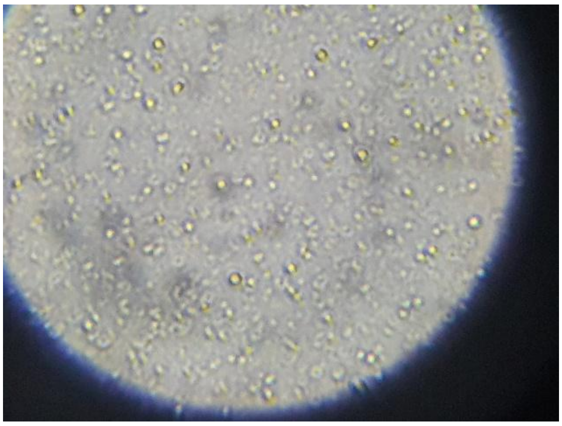
Instructions for teachers

Tell students they are going to look at milk under a microscope.

The students will need to make careful observations of the milk solution with at least 400 × magnification. They may need to let the slide settle, as there may be some initial movement of fat particles due to liquid flowing.

As a group, students should decide what they think is happening and write a response. These responses can then be shared. Students should be encouraged to wonder what Brownian motion means in the context of the other activities they have completed in this topic.

Materials



Per group
- milk (1–2 mL)
- distilled water
- slides and slip covers
- microscope
- Pasteur pipette
- 10 mL measuring cylinder
- paper towel

Per student
- Task sheet: Brownian motion and the particle model

Method
- See the task sheet for student instructions.
- The dilute milk solution can be prepared ahead of time.
- Similarly, pre-prepared milk slides could be made available for students who require additional scaffolding.
- If available, a microscope could be set up to project the slide to support class discussion at the end of the activity.

Task sheet: Brownian motion and the particle model

In this activity, you will prepare a slide of a dilute milk solution and observe a phenomenon called Brownian motion.

Materials

- milk (1–2 mL)
- distilled water
- slides and slip covers
- microscope
- Pasteur pipette
- 10 mL measuring cylinder
- paper towel

Method

- Make up a dilute milk solution by adding 1 mL milk to 6 mL distilled water in a measuring cylinder.
- Place one drop of the dilute milk solution on a microscope slide and place a slip cover over it. Draw through any excess liquid with the paper towel.
- Place the slide on the stage of the microscope and focus using the lowest magnification.
- Record your observations and draw a diagram of what you see.
- Change the magnification to 400 ×. Look very closely for any movement.
- Record your observations and draw a diagram of what you see.

Results

Magnification	Observations	Diagram

Magnification	Observations	Diagram
400 ×		

Processing of results

What do you think is happening to the fat particles in the milk solution?

From what you have observed and discussed, describe Brownian motion and what causes it.

I wonder …

____

____

____

____

____

____

____

____

Work sheet: Properties of states of matter and the particle model

Complete the following table.

State	Property	Particle model explanation	Diagram
solid	fixed shape		
	fixed volume		
	not compressible		
liquid			
gas			

Activity 3: Can gases be poured?

In this activity, students will see that gases, like liquids, can be poured. Carbon dioxide is used, as it is denser than air.

Instructions for teachers

Carbon dioxide can be generated during the demonstration (the instructions for which are given below) or sourced from a gas cylinder, if available.

If generating the carbon dioxide in class, this is an opportunity to introduce students to the downward displacement of water technique for collecting gases with limited solubility in water.

Adjust the task sheet if the carbon dioxide is provided from a gas cylinder.

A video showing the collection of a gas by the downward displacement of water is available at:

- katalyst812 – Displacement of water method to collect gas https://www.youtube.com/watch?v=Ol-2JN01Cfo.

Materials

Per class:

- large conical flask (e.g. 500 mL)
- 3 × gas jar and lid
- water (pneumatic) trough
- beehive stand/shelf
- stopper and tubing
- 250 mL beaker
- wax taper
- tea light candle
- calcium carbonate chips (5 to 10 g)
- 1 to 2 mol L^{-1} hydrochloric acid (200 mL)

Per student:

- Task sheet: Can gases be poured?

Note: Do not use sulfuric acid, as the reaction will slow as calcium sulfate is formed on the outside of the calcium carbonate chips.

Method

Prepare the carbon dioxide

- Set up apparatus as below:

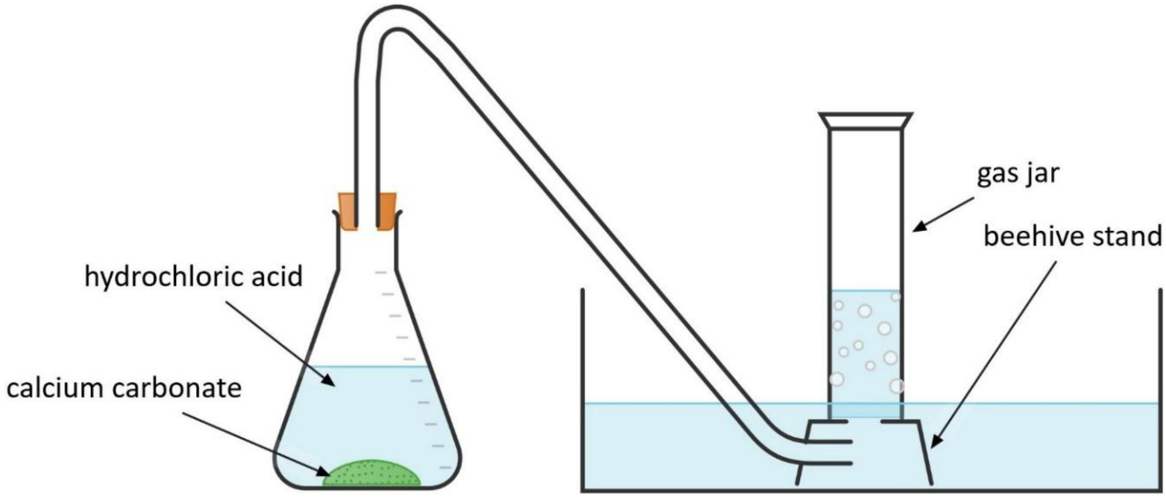


Diagram created with Chemix

- Fill the gas jar with water.
- Invert the gas jar under water in the water trough, so that it is still full of water.
- Add the acid to the calcium carbonate chips and place the stopper in the conical flask.
- Once all the water has been displaced from the gas jar, slide the lid over the mouth of the jar and remove it from the water.
- Repeat this process for several more gas jars.

Pour the carbon dioxide

- Place the lit wax taper into one jar of carbon dioxide to demonstrate that the flame is extinguished. This could be used as an opportunity to introduce the concept of gas tests and that the extinguishing of a flame, while a property of carbon dioxide, cannot be used to determine its identity.
- Place the tea light candle in the bottom of the 250 mL beaker and light.
- Pour the carbon dioxide into the beaker until the candle is extinguished.
- Repeat if required.

Instructions to students

- Complete the task sheet during the demonstration.

Task sheet: Can gases be poured?

Write a prediction for this question.

____

____

____

____

____

____

Watch your teacher prepare the gas jars of carbon dioxide.

Why do you think the gas jar is filled with water before placing it over the delivery tube to collect the carbon dioxide?

____

____

____

____

____

____

The technique used to collect the carbon dioxide is called the ‘downward displacement of water’. It is possible to use this method because carbon dioxide is not very soluble in water.

Record what you observe when a lit wax taper is inserted into a gas jar of carbon dioxide.

____

____

____

____

____

____

Record what you observe when your teacher pours the carbon dioxide into the beaker with the lit candle.

Was your prediction correct? Justify your answer based on the observations you recorded.

Activity 4: Diffusion

Through this activity, students will develop an understanding of diffusion and how it is explained using the particle model.

Instructions for teachers

Review ‘dissolving’ with the class.

For the perfume part of the activity, encourage students to identify when they smell the odour to demonstrate the movement of it throughout the room and that not all students will smell it at the same time. This can be done through a show of hands.

Safety

Be aware of any allergies or reactions students may have to perfumes/room sprays.

Materials

Per class

- large petri dish
- document camera or overhead projector (or students could record with tablets or phones)
- potassium permanganate crystals
- appropriate odour-producing substance e.g. perfume or room spray

Per student

- Task sheet: Diffusion

Method

- Place petri dish under document camera and half-fill it with water.
- Allow time for the water to become still.
- Place a large crystal of potassium permanganate in the centre of the petri dish and record the dissolving of the potassium permanganate in addition to projecting the images.
- Students record their initial observations.
- While the potassium permanganate continues to dissolve, open the perfume/spray the room freshener, and ask students to record their observations.
- After a suitable length of time, refocus the students on the potassium permanganate solution, and ask them to record their observations.

Instructions to students

- Record your observations in the table provided.
- Use the diffusion simulation and the particle model to develop your explanation of what you observed.

Task sheet: Diffusion

Why can I smell dinner cooking, even when I am not in the kitchen?

____

____

____

____

____

Results

Complete your observations of your teacher's demonstrations in the table below.

Action	Initial observations	Final observations
Potassium permanganate is added to water		
Lid is taken off bottle of perfume		

Processing of results

Describe what happened over time when potassium permanganate was added to water.

____

____

____

____

____

____

____

When the lid was taken off the bottle of perfume, how did your location in the room affect your observations?

For each action, explain your observations with the aid of the particle model. Include labelled diagrams in your answer.

Access the diffusion simulation to help you with your answer. Put 20 particles in each side of the box, remove the divider, and observe the particles.

- PhET and University of Colorado Boulder – Diffusion
  https://phet.colorado.edu/en/simulation/diffusion

Activity 5: Gas pressure

In this activity, students will investigate the property of gas pressure, and how it is influenced by the amount of gas (number of particles) present, volume and temperature.

This activity has a hands-on component and a digital component, where students will interact with a simulation.

Instructions for teachers

After students have completed the hands-on part of the activity, they should move to investigating gas pressure with the simulation. The amount of scaffolding required for the activity will depend on the needs of the students. This simulation can be presented to students with minimal direction for an open-ended investigation into the behaviour of gases.

A quick formative assessment opportunity to determine students' understanding of gas pressure could involve students drawing labelled diagrams of balloons and particles to demonstrate the impact of:

- adding or removing particles from a balloon
- heating or cooling a balloon.

Safety

The water temperature should be warm enough to cause a visible change in volume for the balloon, but not so hot that it creates a burn risk.

Materials

Per group

- balloons
- 2 × 1 L beakers
- hot water e.g. kettle
- ice

Per student

- Task sheet: Gas pressure
- Access to PhET simulation (link is on the task sheet)

Instructions to students

- Blow up one balloon and, for each breath, make observations about the size and firmness of the balloon.
- Blow up another two balloons, so that they will fit into the beakers.
- Prepare the two beakers: one with warm water, the other with ice and water.
- Place the balloons in the beakers and observe what happens to the size of the balloons.
- Work through the work sheet for the simulation.

Task sheet: Gas pressure

Blow up a balloon.

As you blow in each breath, record your observations in the table below.

Breaths	1	2	3	4
Size of the balloon				
Firmness of the balloon				

If you continued to blow up the balloon, predict what would happen.

____

____

____

____

____

Set up two beakers as described below and blow up two balloons so that they will easily fit into the beakers.

Place the balloons in the beakers and ensure they are submerged. Record your observations.

Beaker contents	**Observations**
Warm water	
Ice and water	

What do you think is happening to cause these observations?

____

____

____

____

____

____

Gas pressure simulation

Open the following link:

- PhET and University of Colorado Boulder – Gases Intro https://phet.colorado.edu/sims/html/gases-intro/latest/gases-intro_en.html.

Change the temperature to °C and pressure to kPa by using the drop-down arrows next to them.

Simulation 1

- Pump some gas into the box by sliding the pump handle up and down.
- Record the pressure.
- Repeat this four times.
- Describe what you observe occurring in the box.

Pumps of gas	Pressure (kPa)
1	
2	
3	
4	

Record your observations.

____

____

____

____

____

____

____

____

____

____

____

____

Simulation 2

- Reset the simulation.
- Pump in some gas.
- Record the pressure.
- Heat the gas by pushing the slide towards Heat until each of the temperatures in the table is reached. Record the pressure at each point.

Temperature (°C)	**Pressure (kPa)**
27	
50	
100	
150	
200	
250	

Describe the relationship between temperature and pressure.

____

____

____

____

____

____

Explain the relationship with the aid of the particle model.

____

____

____

____

____

Simulation 3

- Reset the simulation.
- Slide the handle on the left-hand side of the box to the right to reduce the volume of the box to a minimum.
- Add one pump of gas.
- Change the Hold Constant setting to Pressure ↕V.
- Progressively add more pumps of gas and record your observations.
- Open the top of the box (make sure that Hold Constant is still set to Pressure ↕V).
- Record your observations.

Adding more gas at constant pressure

____

____

____

____

Opening the box

____

____

____

____

Processing of results

Summarise your findings with the aid of the particle model. Include diagrams if appropriate.

____

____

____

____

____

____

____

Activity 6: Density

In this activity, students will determine the density of some solids and liquids.

Instructions for teachers

Demonstrate the different densities of a number of gases.

Students work through the activity.

Provide students with densities of a number of gases.

Gas	**Density (g/cm^3)**
hydrogen (H_2)	0.0000824
helium (He)	0.000164
nitrogen (N_2)	0.00115
carbon dioxide (CO_2)	0.00180

Students may need assistance to complete the density calculations.

From the data obtained in the activity, students should be able to predict which solids will float in water.

At the end of the activity, work with students to summarise their findings and refine their definition of density.

Materials

Per group

- set of density cubes
- set of liquids, for example:
  - water
  - oil
  - milk
- balance
- 3 × measuring cylinders or syringes (5–10 mL)
- ruler

Per student

- Task sheet: Density

Task sheet: Density

What is density?

____

____

____

____

____

In this activity, you will measure the mass and volume of a number of substances and determine their density.

Density is calculated by using the following formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

where mass is in grams and volume is in cm^3.

Materials

- density cube set
- water (10 mL)
- oil (10 mL)
- milk (10 mL)
- balance
- 3 × measuring cylinders or syringes
- ruler
- calculator

Method

Density of solids

- Measure the sides of one of the cubes and calculate the volume in cm^3.
- Weigh each of the cubes and record the masses on the table below.

Density of liquids

- Weigh a measuring cylinder and record its mass.
- Add 5 mL of water.
- Weigh the measuring cylinder and water, and record the mass.
- Calculate the mass of water in 5 mL.
- Calculate the density of water.
- Repeat these steps for the other two liquids.

Density of gases

- Your teacher will provide you with the density of a number of gases.

Results

Complete the tables below.

Density of solids

Volume of cubes (cm^3): ____________________________

Material	Mass (g)	Density (g/cm^3)

Density of liquids

Note: 5 mL = 5 cm^3

Liquid	Mass of measuring cylinder (g)	Mass of measuring cylinder and liquid (g)	Mass of liquid (g)	Density (g/cm^3)
water				
oil				
milk				

Density of gases

Gas	Density (g/cm^3)

Processing of results

Rank the solids, liquids and gases from most dense to least dense.

____

____

____

____

____

____

____

Rank the states from most dense to least dense.

____

____

____

From your data, list the substances that will sink when placed in water.

____

____

____

____

____

Choose two substances from your data and explain, using the particle model, why one is denser than the other. Use a diagram to support your answer.

____

____

____

____

____

____

____

A substance has the following densities.

State	**Density (g/cm^3)**
solid	1.27
liquid	1.05
gas	0.002

Compare and explain the densities for the different states of this substance with the aid of the particle model. If appropriate, also include labelled diagrams.

____

____

____

____

____

Why do ships – which are made from steel and other materials denser than water – float?

____

____

____

____

____

Activity 7: Heating water

In this activity, students will measure temperature as they heat ice through to boiling and then graph the results.

Instructions for teachers

Review:

- lighting a Bunsen burner
- safety when heating water, including not picking up the beaker until after it has cooled
- reading a thermometer.

The data used for graphing could be an average of each group's data if there is time to collect it. The concept of minimising errors by using multiple trials could be discussed here.

Refer to a prepared set of data for the heating of H_2O (see next page) if the data produced by a group or the class proves unsuitable. The data students obtain may not show a perfectly straight line during the change of state from solid to liquid.

When mixtures are heated and their temperatures measured, they will show a slope during the change of state due to the changing concentration of the mixture.

Materials

Per group

- 250 mL beaker
- ice
- water
- Bunsen burner
- tripod
- gauze mat
- heatproof mat
- thermometer (at least −10 to 110 °C range)
- stopwatch or timer

Per student

- Task sheet: Heating water
- safety glasses
- graph paper

Instruction to students

- Make a prediction about how the temperature of the water will change over time as it is heated from ice through to boiling.
- Heat the water and record the temperature.
- Graph your results.

Heating data for water

Time (min)	Temp (°C)
0	−20
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	10
11	20
12	30
13	40
14	50
15	60
16	70
17	80
18	90
19	100
20	100
21	100
22	100
23	100
24	100
25	100
26	100
27	100
28	100
29	100
30	100
31	100
32	100
33	100
34	100
35	100
36	100
37	100

Time (min)	Temp (°C)
38	100
39	100
40	100
41	100
42	100
43	100
44	100
45	100
46	100
47	100
48	100
49	100
50	100
51	100
52	100
53	100
54	100
55	100
56	100
57	100
58	100
59	100
60	100
61	100
62	100
63	100
64	100
65	100
66	100
67	100
68	100
69	100
70	100
71	100
72	100
73	100
74	120

Task sheet: Heating water

In this activity, you will heat water from a solid until it boils, recording the temperature as you go.

Predict what you think will happen to the temperature as you heat the water.

____

____

____

____

____

Materials

- 250 mL beaker
- ice
- water
- Bunsen burner
- tripod
- gauze mat
- heatproof mat
- thermometer
- stopwatch or timer
- safety glasses
- graph paper

Method

- Half-fill a 250 mL beaker with ice and add approximately 50 mL of water.
- Draw up a table to record the temperature of the water over time.
- Place the thermometer into the ice/water mixture and record the initial temperature.
- Heat the beaker, recording the temperature every two minutes until it has been boiling for eight minutes.
- Graph your results.

Processing of results

How does the shape of your graph compare to your prediction?

____

____

____

____

____

____

Annotate your graph, showing the changes in kinetic and potential energy as the water is heated. (Your teacher will help you with this.)

Explain, with the aid of the particle model, what is happening to the ice when it is melting.

____

____

____

____

____

____

____

Explain, with the aid of the particle model, what is happening to the water between 5 °C and 50 °C.

Activity 8: Sublimation of dry ice

In this activity, students will observe sublimation and explain the change of state using the particle model.

Instructions for teachers

This activity is a demonstration.

Dry ice will need to be ordered ahead of time and can only be stored for a short period of time.

Safety

- Do not place dry ice into sealed glass or plastic containers as it may cause them to shatter.
- Do not allow students to touch dry ice, as it will cause freezer burns.
- Always wear insulated gloves when handling dry ice.

Materials

Per class

- dry ice
- large beaker (1 L)
- tray
- water
- 250 mL conical flask
- balloon (that will fit over the neck of the conical flask)
- insulated gloves
- tongs

Per student

- Task sheet: Sublimation of dry ice

Method

- Place several pieces of dry ice on a metal tray for students to observe. Students record their observations.
- Some water vapour may form around the dry ice due to the cooling of the air.
- Place several pieces of dry ice in the conical flask and attach the balloon. Students record their observations.
- Place several pieces of dry ice in a beaker and half-fill the beaker with water. Students record their observations.

Task sheet: Sublimation of dry ice

Dry ice (solid carbon dioxide) is often used to keep food cool rather than using ice from water. Carbon dioxide is a solid below −79 °C.

Why do you think solid carbon dioxide is called dry ice?

____

____

____

____

____

____

What happens when dry ice is placed on a tray? Record your observations.

____

____

____

____

____

____

What happens when dry ice is placed in a conical flask with a balloon attached? Record your observations and explain them with the aid of the particle theory.

____

____

____

____

____

____

What evidence do we have that carbon dioxide does not form a liquid?

____

____

____

____

____

____

____

____

What happens when dry ice is added to water? Record your observations and explain them.

____

____

____

____

____

____

____

____

____

____

Acknowledgements

Lesson sequence

Lesson 2	Brownian motion information from: American Physical Society. (2005). *This Month in Physics History, Einstein and Brownian Motion*. Retrieved March, 2021, from https://www.aps.org/publications/apsnews/200502/history.cfm

Appendix B

Activity 3	Diagram created with: Chemix. (2024). Retrieved from https://chemix.org