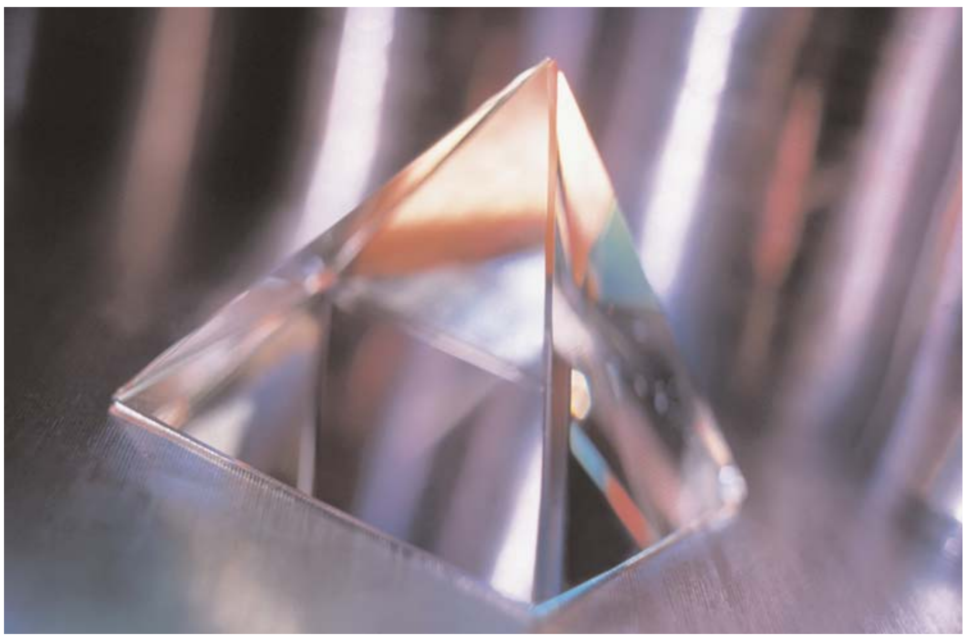
GRADE 11 CHEMISTRY

TOPIC 1:
PHYSICAL PROPERTIES OF MATTER



Topic 1: Physical Properties of Matter

C11-1-01 Describe the properties of gases, liquids, solids, and plasma.
Include: density, compressibility, diffusion

C11-1-02 Use the Kinetic Molecular Theory to explain properties of gases.
Include: random motion, intermolecular forces, elastic collisions, average kinetic energy, temperature

C11-1-03 Explain the properties of liquids and solids using the Kinetic Molecular Theory.

C11-1-04 Explain the process of melting, solidification, sublimation, and deposition in terms of the Kinetic Molecular Theory.
Include: freezing point, exothermic, endothermic

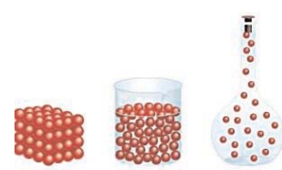
C11-1-05 Use the Kinetic Molecular Theory to explain the processes of evaporation and condensation.
Include: intermolecular forces, random motion, volatility, dynamic equilibrium

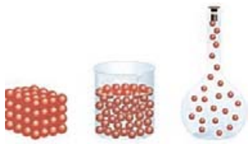
C11-1-06 Operationally define vapour pressure in terms of observable and measurable properties.

C11-1-07 Operationally define normal boiling point temperature in terms of vapour pressure.

C11-1-08 Interpolate and extrapolate the vapour pressure and boiling temperature of various substances from pressure versus temperature graphs.

Suggested Time: 10.0 hours





SPECIFIC LEARNING OUTCOME

C11-1-01: Describe the properties of gases, liquids, solids, and plasma.

Include: density, compressibility, diffusion

(2.0 hours)

SLO: C11-1-01

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

In Grade 7 Science, students were introduced to the particle theory of matter to explain changes of state. The discussion included the absorption or release of energy. Students were also introduced to heating and cooling curves. In Grade 8 Science, students conducted extensive investigations on the properties of fluids, including viscosity, pressure, compressibility, and hydraulics.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL (Know, Want to know, Learned) strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share) found in Chapter 9 of *Senior Years Science Teachers' Handbook* (Manitoba Education and Training)—hereafter referred to as *SYSTH*.

TEACHER NOTES

All the specific learning outcomes in Topic 1 of Grade 11 Chemistry are closely connected to the particulate nature of matter. Review the outcomes, as well as the instructional and assessment suggestions, before starting instruction.

Most students are familiar with three of the four states of matter (i.e., gases, liquids, and solids) through the observations they make in their daily lives. To understand the development of the kinetic molecular model, however, students should review the differences in the states of matter and the processes required to interchange them. If time permits, have students melt, boil, and condense water using observations to discuss the properties of the more common states of matter (e.g., density, volume, shape, compressibility, diffusion). If experimental evidence is not possible, then ask students to recall observations from their past experience and

General Learning Outcome Connections

GLO C6: Employ effective communication skills and use information technology to gather and share scientific and technological ideas and data.

GLO C7: Work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities.

GLO C8: Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

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knowledge (e.g., boiling water on the stove, sublimation of solid water from washing in sub-zero weather, melting and solidification of candle wax, evaporation of acetone from hands).

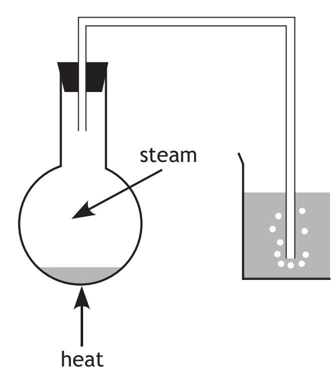
Most resources provide a good explanation of the physical characteristics of the most common three states of matter: *gases, liquids*, and *solids*. The fourth state, *plasma*, can be simply defined as a gaseous mixture of positive ions and electrons. Due to the unstable nature of these particles, the only way to have a large number of these energetic particles coexisting is at temperatures over 100 million degrees Celsius. The challenge for engineers is to contain high-energy plasmas once they are created (Chang 964).

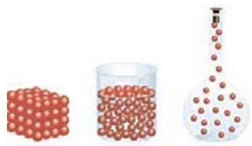
Plasmas are the most common form of matter in the universe, comprising 99% of the visible universe, but are the least common on Earth. Examples include the aurora borealis, lightning, stars, fluorescent lights, and plasma TVs.

Discrepant Event Activities

Discrepant events provide opportunities to illustrate some of the physical properties of the three states of matter. It is not intended that all activities suggested below be done. Select activities and demonstrations appropriate for the class.

1. Add water to the ¾ mark in a eudiometer tube, and then add ethanol to fill the tube completely. Seal the tube and mix contents by carefully inverting the tube. Have students observe the change in volume and explain what they see.
2. **Demonstrating Diffusion on an Overhead Projector** (see Appendix 1.1): Sprinkle a few crystals of paradichlorobenzene into one compartment of a four-quadrant petri dish and a few crystals of iodine into the opposite compartment. Place the petri dish on an overhead projector stage. Add 1 or 2 mL of acetone to one of the remaining quadrants of the petri dish and cover it with the supplied top. Have students observe, record, and explain what happens.
3. **A "Real" Water Fountain** (see Appendix 1.2): Heat a small quantity of water in a 1 L Florence flask to displace the air. When the flask is filled with water vapour or steam, stop the heating. Note that the steam condenses and the pressure inside the flask drops. Cold water from the beaker is then pushed into the flask by atmospheric pressure, with dramatic results. (See diagram.) This event could be used to address learning outcomes C11-2-03 and C11-2-04 and atmospheric pressure.





SPECIFIC LEARNING OUTCOME

C11-1-01: Describe the properties of gases, liquids, solids, and plasma.

Include: density, compressibility, diffusion

(continued)

Particulate Activities

Solids

The motion of particles in a solid can be demonstrated by placing a one metre by one metre square of tape on the floor and having nine student volunteers try to move around in the square. Students should find that their motion is limited to "bumping" into each other.

Liquids

The motion of particles in a liquid can be demonstrated using marbles. Spread out the marbles evenly to fill the bottom of a container. The volume they occupy cannot be reduced. When the container is swirled and tipped, the marbles flow out onto a table.

Gases

1. The motion of particles in a gas can be demonstrated using an air hockey puck and table. The puck travels in a straight line until it hits the side of the board, and then rebounds in a straight line in a new direction.
2. Use effervescent tablets, water, and a candle to show that a gas can be poured. Alternatively, place dry ice into warm water so that students can "watch" the cooled carbon dioxide vapour fall to the floor.

Activities/Demonstrations

It is not intended that all activities/demonstrations be done. Select the activities and demonstrations appropriate for the class.

1. Have students research the densities of a number of metals, liquids, and gases. Ask students to organize them according to densities to illustrate the differences between solids, liquids, and gases. Many websites provide information about the physical properties of elements and compounds. Use the *CRC Handbook of Chemistry and Physics* to find densities.
2. Demonstrate the compressibility of gases using a simple air pump.
3. Put a few drops of any flavouring (e.g., peppermint) into a balloon. Inflate the balloon. Students will be able to smell the flavouring through the rubber as it diffuses through the membrane of the balloon.
4. Open a container of a volatile liquid, such as perfume or butyric acid, somewhere unnoticed in the room and wait for students' reaction.

SKILLS AND ATTITUDES OUTCOMES

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

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5. The classical demonstration for quantitative or qualitative diffusion is with ammonium hydroxide and hydrochloric acid. Most textbooks describe a procedure. Basically, a cotton plug soaked with ammonium hydroxide is placed into the end of a 60 cm piece of glass tubing. Another cotton plug soaked with hydrochloric acid is simultaneously placed in the other end of the tube. As the vapours diffuse along the tube, a ring of ammonium chloride is produced where the NH_3 and HCl particles meet. As NH_3 particles have less mass, the ring of product should be closer to the heavier vapour. (See Dingrando, *et al.* 388.)

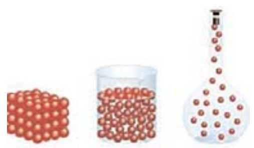
   Extension: By measuring the distance from each plug of cotton to the product formed, a distance ratio can be calculated to establish a relationship between the relative masses of the molecules in question. Using Graham's Law of Diffusion will produce a ratio of 1:5.
6. Have students conduct a heating curve investigation for water to review prior knowledge and to reinforce safety rules in the laboratory. Students could collect data either manually using a thermometer or by using a calculator-based laboratories (CBL) system.
7. **Popping the Kernel: Modelling the States of Matter** (see Appendix 1.3): This simple activity (Hitt, White, and Hanson 39–41) provides students with the opportunity to examine the states and physical properties of matter.

TEACHER NOTES

Not all forms of matter can be readily described as solids, liquids, or gases. In the case of liquid crystals, the ability to control the orientation of the molecules contained in the crystals allows industry to produce materials with high strength or unique properties. Liquid crystal displays (LCDs) are used in watches, thermometers, calculators, and laptop computers. (For a discussion of liquid crystals and ceramic materials, see Silberberg 462.)

Amorphous (Greek for "without form") materials have an irregular arrangement of particles. These substances do not have a definite melting point. There are many examples of such materials (e.g., peanut butter, candle wax, cotton candy, glass, rubber, plastic, asphalt). Amorphous carbon is produced from the decomposition of carbon compounds. When animal bones decompose, bone black is produced. It is used as a pigment and in the refining of sugars. The decomposition of coal produces the coke that is used in dry cell batteries.

Teachers may wish to discuss the term *allotropes*—different particle arrangements of the same substance. For example, carbon can exist as tetrahedral crystals (diamond), sheets (graphite), cage-like balls (buckminsterfullerenes), and cage-like tubes (nanotubes).



SPECIFIC LEARNING OUTCOME

C11-1-01: Describe the properties of gases, liquids, solids, and plasma.

Include: density, compressibility, diffusion

(continued)

SUGGESTIONS FOR ASSESSMENT

Research Activity

Have students research and report on plasma TVs, monitors, LCDs, and so on. Use the Rubric for Assessment of Research Skills found in Appendix 10 to assess student work.

Knowledge Chart

Provide students with a Knowledge Chart (see *SYSTH* 9.25). Have students complete the chart, including representation of the states of matter.

Visual Displays

Have students create models to represent their view of the particles in the four states. Use the Rubric for Assessment of Student Presentation found in Appendix 10 to assess the models.

Journal Writing

Many unusual materials are discussed in relation to learning outcome C11-1-01. One of the discussion topics for journal writing might be a commentary on the longevity of plasma TV screens compared to their cost.

SKILLS AND ATTITUDES OUTCOMES

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

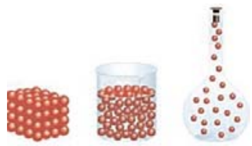
C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

LEARNING RESOURCES LINKS

Chemistry (Chang 434)
Chemistry (Zumdahl and Zumdahl 449)
Chemistry: The Central Science (Brown, *et al.* 407)
Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 339)
Chemistry: The Molecular Nature of Matter and Change (Silberberg 419, 462)
Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 384)
Introductory Chemistry: A Foundation (Zumdahl 398)
McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 417)
Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 262)
Nelson Chemistry 12: College Preparation, Ontario Edition (Davies, *et al.* 330)
Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 456)

Selecting Learning Resources

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education, Citizenship and Youth website at: <http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html>.



SPECIFIC LEARNING OUTCOME

C11-1-02: Use the Kinetic Molecular Theory to explain properties of gases.

Include: random motion, intermolecular forces, elastic collisions, average kinetic energy, temperature

(1.5 hours)

SLO: C11-1-02

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

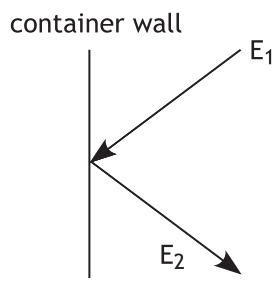
As was mentioned for learning outcome C11-1-01, students in earlier grades have been introduced to phases and phase changes in terms of energy transfer and the particle theory of matter.

TEACHER NOTES

This learning outcome begins to provide an explanation for the existence of particles and the development of a more complete particle model. The Kinetic Molecular Theory was proposed to explain the observable properties of gases. Each chemistry text seems to put a different spin on the theory, as well as variations in the number of postulates.

If gas particles in a container at constant temperature are in constant motion, they must eventually collide with other particles, as well as with the container walls. These particles exert pressure when they collide with the walls of their container. *Pressure* is defined as force per unit area.

Lead students through the following logic:



A particle collides with the container wall. Its initial energy is E_1 and its energy after the collision is E_2.

General Learning Outcome Connections

GLO A1: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

GLO A2: Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO D4: Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-U2: Demonstrate an understanding of chemical concepts.

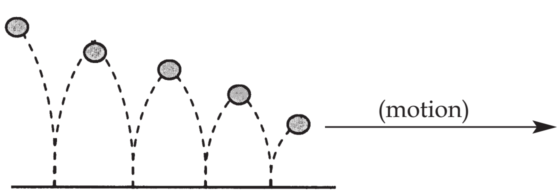
Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives…

Three options are possible:

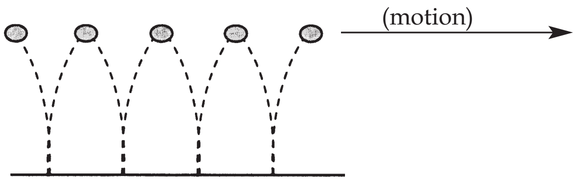
- If $\mathbf{E_1 > E_2}$ then the total energy loss due to all the collisions in the container would result in a pressure drop over time.
- If $\mathbf{E_1 < E_2}$ then the total energy gain of all the collisions would result in a pressure increase.
- If $\mathbf{E_1 = E_2}$ then there would be no loss of energy, the total energy of all the collisions would not change, and the pressure of a gas in a container at a constant temperature would remain constant. A barbecue propane tank is a good example of this phenomenon. If the barbecue is not used, the tank will maintain a constant pressure, provided the temperature is not changed.

For the following two diagrams, the energy of the ball in the first diagram decreases as it collides with the floor, whereas the particle in the second diagram has exactly the same energy after the collision as it did before. These are called *perfectly elastic* or *elastic* collisions.

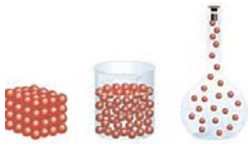
Inelastic Collisions (loss of energy)



Elastic Collisions (no loss of energy)



In Grade 11 Chemistry, intermolecular forces should be discussed as general forces and not as three different forces: dipole-dipole forces, London dispersion forces, and hydrogen bonding. A further discussion of intermolecular forces will occur in relation to learning outcomes (C11-1-04, C11-1-05) that address phase changes.



Specific Learning Outcome

C11-1-02: Use the Kinetic Molecular Theory to explain properties of gases.

Include: random motion, intermolecular forces, elastic collisions, average kinetic energy, temperature

(continued)

Activity/Demonstration

1. Illustrate the properties of gases with a demonstration. Plug the end of a bicycle pump while pushing in the handle, thereby causing the gas inside the tube to compress.
2. A piece of demonstration equipment called an Atomic Trampoline Kit is available from the Institute for Chemical Education. See *CHEM 13 NEWS* 327 (Feb. 2005): 2.

Research

Have students research the three most prominent scientists whose work led to the establishment of the Kinetic Molecular Theory:

- Rudolf Clausius
- James Clerk Maxwell
- Ludwig Boltzmann

Student research could be presented as a written assignment in the form of

- letters between scientists
- bulletin board displays
- technical papers

Graphic representations could include

- diagrams
- posters
- charts

Teacher Notes

The following diagrams can be found in Appendix 1.4: Kinetic Energy Distribution. The first diagram illustrates how scientists might determine that the particles in a sample of vapour would have a range of speeds. The molten tin vapour is accelerated towards a collimator that produces a narrow beam of particles. The beam is interrupted by a rotating disk D_1 that creates bursts of vapour particles that travel down the evacuated tube towards disk D_2.

After the disks have rotated many times, the paper attached to D_2 is removed and cut into sections according to the second diagram. The paper slices are carefully massed. The mass of each slice reflects the number of particles landing on each section of the plate. The fastest would land on the sections closer to the slit (i.e., sections 1, 2, 3, etc.).

Skills and Attitudes Outcomes

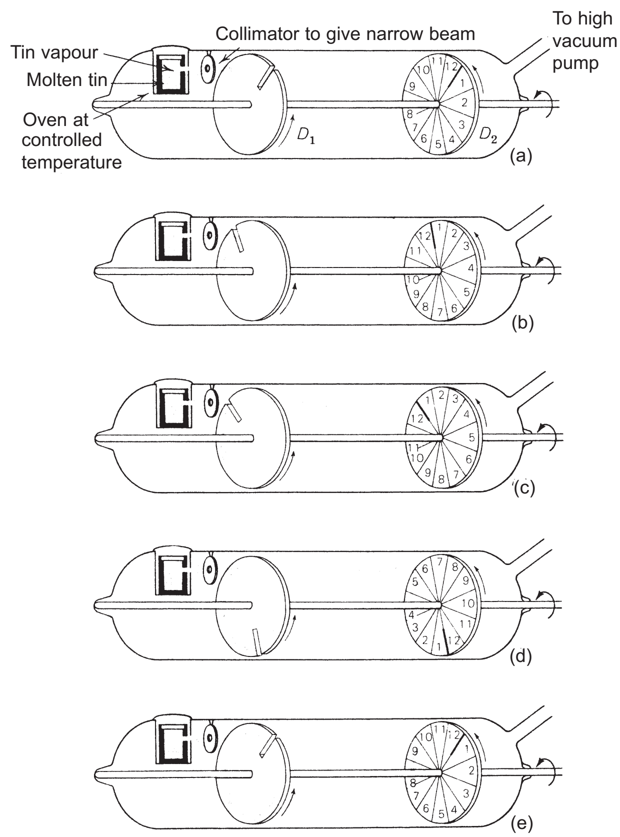
C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

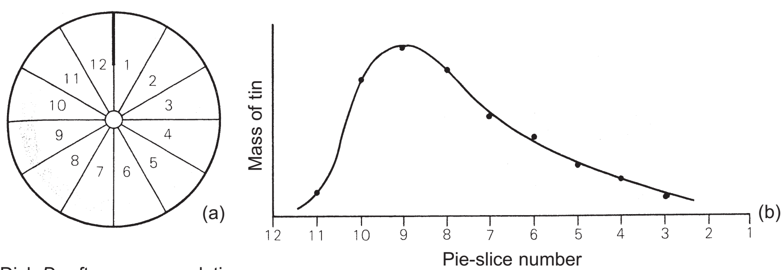
C11-0-U2: Demonstrate an understanding of chemical concepts.

Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives…

Rotating disk used to measure atomic or molecular velocities.

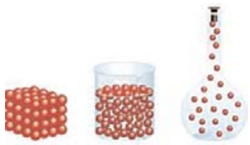


The relative distribution of atomic or molecular velocities obtained from the rotating disk.



Disk D_2 after many revolutions

Figures: From *Chemistry: Experimental Foundations* by Robert W. Parry, Phyllis M. Dietz, Robert L. Tellefsen, & Luke E. Steiner © 1975 by Prentice Hall. Used by permission of Pearson Education, Inc.



SPECIFIC LEARNING OUTCOME

C11-1-02: Use the Kinetic Molecular Theory to explain properties of gases.

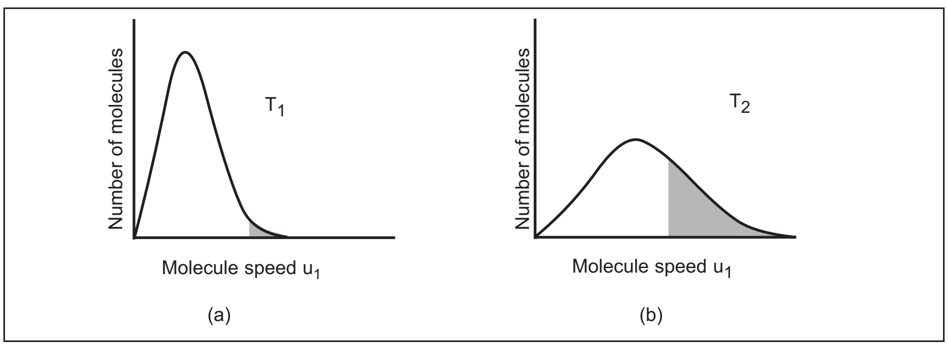
Include: random motion, intermolecular forces, elastic collisions, average kinetic energy, temperature

(continued)

TEACHER NOTES

Once students understand the relationship of the average kinetic energy and temperature, show them what occurs in a sample of gas when the temperature is increased. Ask them to predict what the curve might look like in the rotating disk system if the temperature was increased.

The following diagram illustrates how the number of particles having a speed of u_1 increases as the temperature is increased. Remind students that since KE = $1/2\ mv^2$, the diagrams also represent the relative change in average kinetic energies for a sample of gas in which the temperature has been increased. Ask students how they might measure the relative increase in the shaded area between the two diagrams.



A piece of demonstration equipment called a Stoekle Tube could be used to show how increasing the temperature increases the speed of particles. The tube could also be used for learning outcome C11-1-03 to illustrate how the rate of evaporation is increased by an increase in temperature.

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that could be used for assessment.

Pencil-and-Paper Tasks

1. Students should be able to provide examples of situations where macroscopic events resemble elastic collisions (e.g., billiards, pool, hockey, super balls, air table, computer games).

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-U2: Demonstrate an understanding of chemical concepts.

Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives…

2. Students should be able to explain the observable properties of gases using the Kinetic Molecular Model. To encourage students to gain confidence in their own explanations of concepts before explaining them to the class, have them use the following strategies:
    - Concept Overview (see template in *Success for All Learners* 6.112)
    - Listen-Draw-Pair-Share (*Success for All Learners* 6.97)

Visual Displays

Student groups could review the postulates of the Kinetic Molecular Theory and display their knowledge in graphic representations such as

- diagrams
- posters
- charts
- bulletin boards

Journal Writing

Have students provide other examples that would illustrate *perfectly elastic collisions*.

LEARNING RESOURCES LINKS

Chemistry (Chang 191)

Chemistry (Zumdahl and Zumdahl 212)

Chemistry: The Central Science (Brown, *et al.* 386)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 342)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 197)

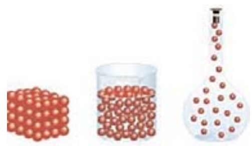
Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 385)

Introductory Chemistry: A Foundation (Zumdahl 383)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 421)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 16)

Success for All Learners (Manitoba Education and Training 6.97, 6.112)



SPECIFIC LEARNING OUTCOME

C11-1-03: Explain the properties of liquids and solids using the Kinetic Molecular Theory.

(1.0 hour)

SLO: C11-1-03

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

In Grade 7 Science, students were introduced to the particle theory of matter to explain changes of state. Discussion included the absorption or release of energy as a given phase change occurred. Students were also introduced to heating and cooling curves. There was, however, no discussion of intermolecular forces.

Assessing Prior Knowledge

Prior knowledge can be reviewed and/or assessed by using any of the KWL forms (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

Most chemistry textbooks relate the properties of solids and liquids to the Kinetic Molecular Theory.

Ask students to relate the properties of liquids and solids to the distances between particles, intermolecular forces of attraction, and the average kinetic energy of the particles. Students should understand that as the temperature increases, random motion increases, causing particles to move further apart and, therefore, reducing the strength of intermolecular forces. The overall reduction in forces holding particles in a particular phase allows phases to change as energy is absorbed. As each element and compound has a unique structure, it is reasonable to deduce that each has unique melting and boiling points.

Wherever possible, students should determine differences in the properties and structure of liquids and solids for themselves. Most textbooks will provide some physical data. The *CRC Handbook of Chemistry and Physics* is another resource.

General Learning Outcome Connections

GLO B3: Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

GLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

GLO C1: Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.

GLO C2: Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

GLO C3: Demonstrate appropriate problem-solving skills when seeking solutions to technological challenges.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

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Encourage students to make lists of the viscosity and density of common substances. A review of the data collected will enable students to relate the unique physical properties to their particulate structure.

Solids can be categorized into two main categories: *crystalline* and *amorphous*. There are four types of crystalline solids:

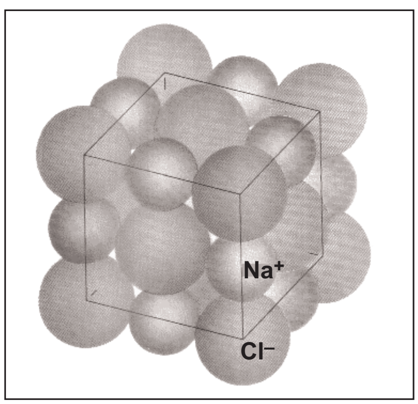
- covalent network (e.g., diamond, graphite)
- ionic (e.g., NaCl, CaF_2)
- molecular (e.g., I_2 , S_8)
- metallic (e.g., Cu, Ag)

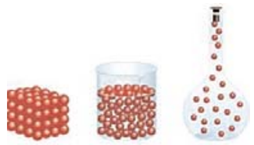
Amorphous solids are those that lack a regular three-dimensional arrangement of atoms (e.g., glass, lampblack).

The crystal structures that should be emphasized are those for ionic and molecular solids. Most chemistry texts provide a good description of unit cell structures, lattice structures, and various types of crystal structures. Students should only be exposed to the simplest of crystal structures.

Ionic Compounds

Using a microscope, students can examine the macroscopic characteristics of a crystal of salt. They should be able to see the macroscopic regular cubic structure and then extend their findings to the molecular level. Students should understand the concept with relationship to the diagram below.



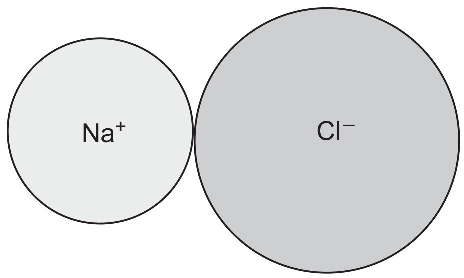


SPECIFIC LEARNING OUTCOME

C11-1-03: Explain the properties of liquids and solids using the Kinetic Molecular Theory.

(continued)

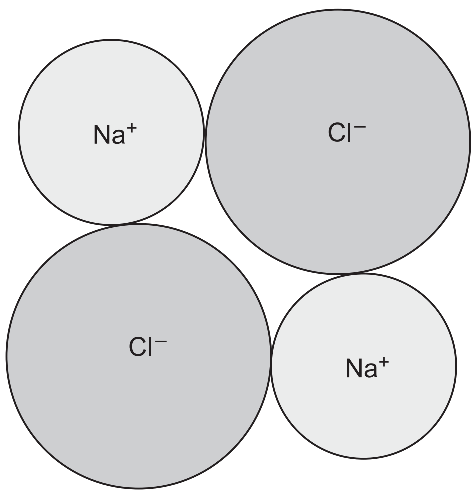
A sodium and a chloride ion:



or Na — Cl

Oppositely charged ions are held together by an electrostatic force of attraction.

A two-dimensional array of two sodium ions and two chloride ions:



or Na — Cl
| |
Cl — Na

Skills and Attitudes Outcomes

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

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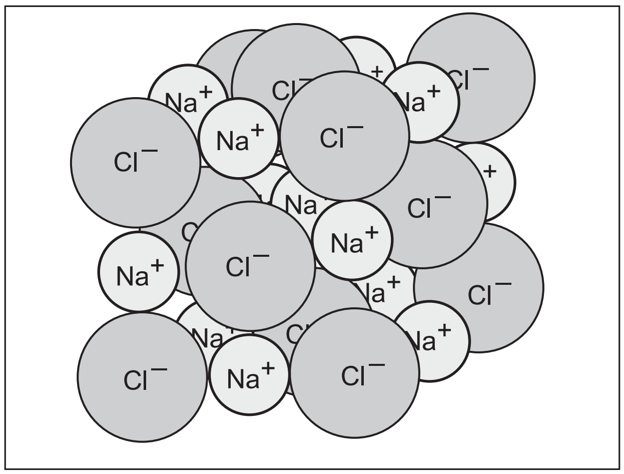
A three-dimensional cubic lattice containing sodium and chloride ions:

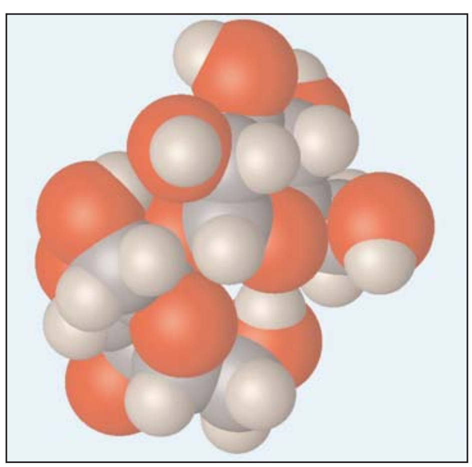


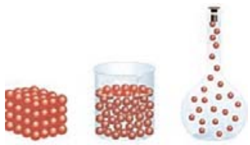
Covalent Compounds

Rather than looking at a sugar crystal macroscopically, students can view an electron micrograph picture (or similar representation) of a crystal of sugar. In these compounds, crystals are still formed but the molecules within the crystals are held together by covalent bonds.

Teacher Notes

A *molecular model of sugar* is shown below:



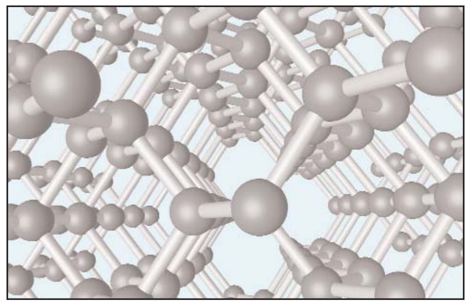


SPECIFIC LEARNING OUTCOME

C11-1-03: Explain the properties of liquids and solids using the Kinetic Molecular Theory.

(continued)

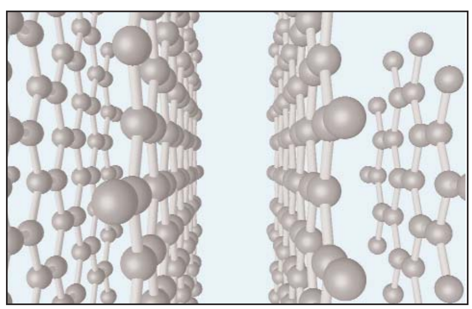
The *crystal structure of diamond*, one of the allotropic forms of carbon, can be seen below:



The following articles provide additional information about diamonds and their properties:

- Brubacher, Lew. "Diamonds." *CHEM 13 NEWS* 327 (Feb. 2005): 1, 4–6.
- Clinton, Laura, and Catheryn Lee. "Diamonds in the Snow." *CHEM 13 NEWS* 327 (Feb. 2005): 6–7.

Another allotropic form of carbon is *graphite*, represented in the diagram below:



Glass is often defined as an optically transparent fusion product of inorganic material that has been cooled to a solid state without crystallization.

Melting sand normally requires very high temperatures. However, if sodium is added to ordinary sand it acts as a flux to lower the melting point of the silica sand (silicon dioxide, SiO_2) so it can melt and more easily form a "glass." By adding sodium to the mix, the viscosity of a glass can be tuned to specific requirements. The stoichiometry of glass is not fixed and so the addition of various components causes a proportional change in the properties of the glass. The addition of sodium carbonate results in common glass. By adding inorganic elements to the mix, various colours are produced (e.g., gold causes a ruby red colour in the glass,

SKILLS AND ATTITUDES OUTCOMES

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C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

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whereas the addition of antimony causes a canary yellow colour. Glass is macroscopically a solid, with melting temperatures from 1000°C to 1500°C. A crystal structure is completely absent due to rapid cooling.

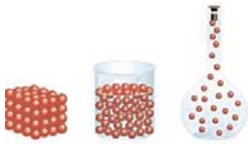
About 800 types of glass are used today. The addition of B_2O_3 to the mix forms a glass that has a low coefficient of expansion commonly known as borosilicate glass or Pyrex®. Glass that contains potassium oxide is so hard that it is used to manufacture glass lenses.

One of the most important uses of glass occurs in the manufacture of optical cable. Because impurities cause so much variation in the properties of glass, the glass used in the formation of optical fibres must be ultra-pure, usually less than 1 ppb. The uniqueness of an optical fibre is that it has total internal reflectance or 100% transmission of the input signal. Optical data travelling along an optical fibre need only be regenerated every 100 km, whereas a similar signal travelling through copper cable must be regenerated every 4 to 6 km. Another interesting comparison is that a copper wire would require 25,000 times as much mass as an optical fibre to send the same data.

It has been suggested that a new use for impervious glass products might be the storage of radioactive byproducts. Currently, thousands of tonnes of highly radioactive materials are stored in a variety of containers all over North America. These containers have been found to be less resistant to age than was once thought. There is now evidence that some of these "safe" containers are leaking. An idea that has recently surfaced is to embed radioactive materials in glass to make them completely impervious to solvents and decay. It has been found that glass can hold up to 30% of its mass as waste materials.

Laboratory Activity

The lab activity Bond Types and Conductivity (see Appendix 1.5) asks students to identify the type of bonding based on electrical conductivity and probeware.



SPECIFIC LEARNING OUTCOME

C11-1-03: Explain the properties of liquids and solids using the Kinetic Molecular Theory.

(continued)

Activities

Have students:

1. Display various physical data as a spreadsheet and graph, according to the technical expertise and experience of students, and the equipment available to them.
2. Sketch simple crystal shapes.
3. Make a representation of crystals using mini-marshmallows and toothpicks.
4. Draw a concept map of the various types of solids, including examples.
5. Research different types of glasses and their uses. (To assist students with their research, provide them with a copy of Appendix 1.6: Chemistry Article Review Form.)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Research Reports

Have students, individually or in small groups, research and report on any of the topics related to learning outcome C11-1-03. The information collected could then be presented as

- written reports
- oral presentations
- bulletin board displays
- multimedia presentations

Visual Displays

Students could present their collected material using

- posters
- pamphlets
- bulletin boards
- models

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

Journal Writing

1. Have students write opinions or reflections regarding the storage of radioactive waste by-products in less than safe containers.
2. Have students reflect on the impact that optical fibres have had on electronics and technology.

LEARNING RESOURCES LINKS

Chemistry (Chang 443)

Chemistry (Zumdahl and Zumdahl 449)

Chemistry: The Central Science (Brown, *et al.* 407)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 344)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 419)

CRC Handbook of Chemistry and Physics (Weast)

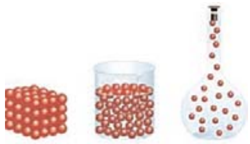
Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 396)

Introductory Chemistry: A Foundation (Zumdahl 399)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 262, 268)

Nelson Chemistry 12: College Preparation, Ontario Edition (Davies, *et al.* 330)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 467)



SPECIFIC LEARNING OUTCOME

C11-1-04: Explain the process of melting, solidification, sublimation, and deposition in terms of the Kinetic Molecular Theory.

Include: freezing point, exothermic, endothermic

(2.0 hours)

SLO: C11-1-04

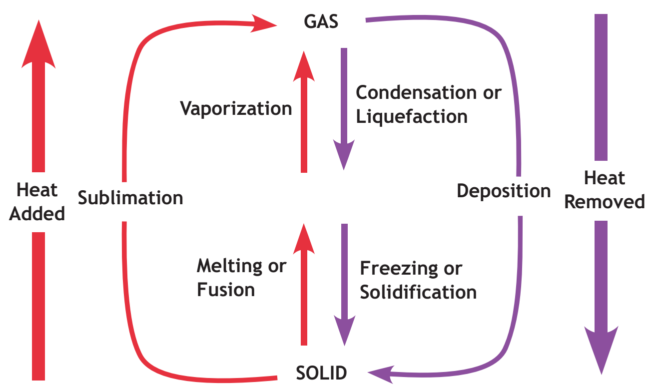
SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

In Grade 7 Science, students were introduced to the particle theory of matter to explain changes of state. Discussion included the absorption or release of energy as a given phase change occurred. Students were also introduced to heating and cooling curves.

Students should have a good understanding of the three major states of matter and phase changes, both from previous science courses and from general experience.

A typical phase diagram illustrating students' prior knowledge might look as follows:



General Learning Outcome Connections

GLO B3: Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

GLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

GLO C1: Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.

GLO C2: Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

GLO C3: Demonstrate appropriate problem-solving skills when seeking solutions to technological challenges.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO D4: Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts.

GLO E4: Recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them.

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

Assessment of Prior Knowledge

Either question students regarding their prior knowledge or have them complete one of the following:

- Concept Overview sheet (*Success for All Learners* 6.112)
- Knowledge Chart (*Success for All Learners* 6.95)

TEACHER NOTES

Introduce the terms *endothermic* and *exothermic processes*. Then ask students whether they can add energy arrows to the diagram they have produced, indicating heat added or heat removed. Students may also be able to sketch heating curves and cooling curves for water.

Before students can fully understand the particle mechanics of phase change, they need to understand the forces that are involved. Students should be able to relate the energy required to cause a solid to change into a liquid to the intermolecular forces of attraction holding the particles together. These forces account for variations in melting point, boiling point, and other characteristic properties of solids, liquids, and gases. During phase changes, the addition of heat energy causes an increase in kinetic energy, which is used to break the forces of attraction between particles so that they can change from one state to the next. Particles that are left behind continue to absorb additional energy from the added heat until they are able to change state.

Most chemistry texts provide a good explanation of phase changes. Emphasize to students that a minimum amount of kinetic energy is required for particles to change to the next phase in order to overcome the intermolecular forces of attraction holding the particles together. This is often called the *threshold energy*. This energy is released for the reverse exothermic phase change. Recall the kinetic energy distribution curve diagrams discussed in the Teacher Notes for learning outcome C11-1-02. Even though the diagrams were derived experimentally for gases, scientists believe they apply to all phases of matter.

Specific Learning Outcome

C11-1-04: Explain the process of melting, solidification, sublimation, and deposition in terms of the Kinetic Molecular Theory.

Include: freezing point, exothermic, endothermic

(continued)

Demonstration Activities

It is not intended that all demonstration activities should be done. Select activities appropriate for the class. Most students can provide examples of sublimation (e.g., mothballs, solid air fresheners, dry ice).

1. If there is access to a correctly functioning fume hood, demonstrate the gentle warming of a few crystals of solid iodine in a large test tube.
2. The deposition of iodine vapour was used in the past in fingerprint detection. A procedure can be found in Appendix 1.7: Making Fingerprints Visible.
3. Dry ice is an excellent demonstration substance, although it sublimes rapidly even when kept in a freezer.
4. Other solids, such as benzoic acid, will also sublime.
5. If a spare CO_2 fire extinguisher is available and permission is obtained for its use in the school, the cylinder can be partially discharged into a cloth bag. Carefully examine the resulting solid and discuss observations with students.

Discrepant Event

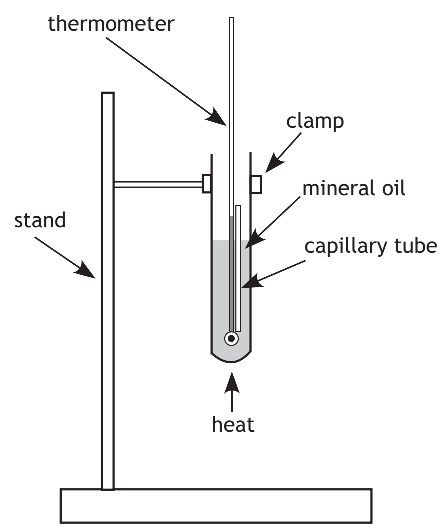
Place several mothballs or mothball flakes in a small beaker over a very low flame. Secure a round-bottomed flask containing ice water over the beaker. Slowly heat the mothballs until they have all disappeared. Lift the flask to display the crystals that have formed on the bottom of the flask. Have students write down their observations and a conclusion. **Caution:** This event should be performed in a fume hood.

Laboratory Activities

Ask students to determine the melting point (MP) of a number of solids and then use this information to identify an unknown. For this experiment, see Appendix 1.8: Probeware Investigation: Determining Melting Points.

Any of the following solids could be used for this lab:

- stearic acid MP 69.6°C
- palmitic acid MP 63.0°C
- thymol MP 50.0°C
- maleic anhydride MP 53.0°C
- cinnamic acid MP 42.0°C



SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

Research Activities

Have students research the following:

1. Research freeze-drying, or cryogenics. The information could be presented as a poster, an article, a *PowerPoint* presentation, a class presentation, or a debate. Cryogenics will be discussed again when students are introduced to Charles's Law, Kelvin, and absolute zero.
2. Research the mean average temperatures of interior and coastal regions to determine the moderating effect of large bodies of water.
3. Research the operation of simple cooling devices (e.g., camp cooler—canvas bag that, when filled with water, keeps cool from the evaporation of water from the canvas) and other devices such as refrigerators and air conditioners

SUGGESTIONS FOR ASSESSMENT

Laboratory Reports

The demonstrations and events outlined for learning outcome C11-1-04 could be assessed as either formal lab reports using the Laboratory Report Format (see *SYSTH* 14.12) or by using questions and answers from the data collected from the various activities.

Paper-and-Pencil Tasks

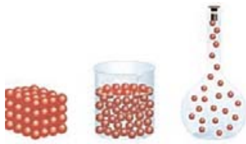
Students should be able to use the Kinetic Molecular Theory to explain how melting, solidification, sublimation, and deposition occur.

Research Reports

Student research and reports could be presented as

- written reports
- oral presentations
- bulletin board displays
- multimedia presentations

The research assignments could be assessed using any of the rubrics designed specifically for research projects (see Appendix 10).



SPECIFIC LEARNING OUTCOME

C11-1-04: Explain the process of melting, solidification, sublimation, and deposition in terms of the Kinetic Molecular Theory.

Include: freezing point, exothermic, endothermic

(continued)

LEARNING RESOURCES LINKS

Chemistry (Chang 462)

Chemistry (Zumdahl and Zumdahl 489)

Chemistry: The Central Science (Brown, *et al.* 407)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 364)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 419)

Chemistry with Computers (Holmquist and Volz, Freezing and Melting of Water)—Available from Vernier: <http://www.vernier.com/chemistry/>

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 404)

Glencoe Chemistry: Matter and Change: CBL Laboratory Manual – Teacher Edition (LAB 3: Melting and Freezing Points, 9)

Introductory Chemistry: A Foundation (Zumdahl 401)

PASPort Explorations in Chemistry Lab Manual (PASCO Scientific)—Available from PASCO: <http://www.pasco.com/hsmanuals/ps2808.html>

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 485)

Success for All Learners (Manitoba Education and Training 6.95, 6.112)

Skills and Attitudes Outcomes

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

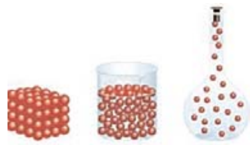
Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

Notes



SPECIFIC LEARNING OUTCOMES

C11-1-05: Use the Kinetic Molecular Theory to explain the processes of evaporation and condensation.

Include: intermolecular forces, random motion, volatility, dynamic equilibrium

C11-1-06: Operationally define vapour pressure in terms of observable and measurable properties.

(1.5 hours)

SLO: C11-1-05
SLO: C11-1-06

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

The Kinetic Molecular Theory is discussed in some detail in relation to learning outcome C11-1-04. Students should be familiar with the components of the particle theory and the Kinetic Molecular Theory, and all the related concepts such as average kinetic energy and elastic collisions.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

Most students are well aware of the process of vaporization, evaporation, and the absorption of energy. Reintroduce these concepts through observation. The following activities will focus students' knowledge and allow them to confirm operational definitions. It is not intended that all activities and discrepant events be done. Select those appropriate for the class.

Activities

A number of activities can be done to measure qualitatively the differences in the intermolecular forces in liquids by measuring the relative rates of evaporation. The following liquids are suggested for the first two activities: water, ethanol, methanol, acetone, isopropyl alcohol, and cyclohexane.

1. Swab each liquid onto an impermeable smooth surface and observe the time it takes for the liquid to disappear. **Do not** place on skin.
2. Place a fixed volume of each liquid on a watch glass and record the mass loss as a function of time on a centigram balance.

General Learning Outcome Connections

GLO C3: Demonstrate appropriate problem-solving skills when seeking solutions to technological challenges.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO E4: Recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them.

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

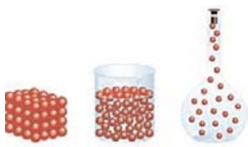
3. The Vapour Pressure with Pop activity (see Appendix 1.9) involves a volatile liquid and a sealed container. It is possible for students to design variations on this activity. Essentially, a small amount of pentane or other very volatile liquid such as acetone is placed into a tennis-ball can with a plastic lid that closes tightly. When students roll the tube in their hands, they will immediately feel the drop in temperature as the liquid cools. When enough pressure has been created, the cap will fly off with a loud noise. This activity could be modified to be quantitative. The Material Safety Data Sheet for each substance should contain the vapour pressure of the liquid. By calculating the surface area of the tube, the total pressure can be determined. For a typical tennis-ball can and petroleum ether, the pressure is about 60 psi. (See Appendix 1.9 for more details.)

Discrepant Events

1. Place one thermometer in the breeze of a fan and place an identical thermometer near the fan but not in the breeze. Ask students to predict which thermometer will show the lowest temperature. Discuss the results. Place some wet cotton gauze around the bulbs of both thermometers and repeat. Discuss the results. Calculator-based laboratories (CBLs) or microcomputer-based laboratories (MBLs) could be used to collect the data. References are provided in the Learning Resources Links.
2. While holding a burning match, quickly blow out a candle that has been burning with a strong flame and place the match in the smoke trail. Have students observe and discuss the results.

TEACHER NOTES

In learning outcome C11-1-04, students were introduced to the concept that a minimum amount of energy is required to overcome the intermolecular forces of attraction that hold particles in a crystal structure. If this energy were exceeded, particles would tend to break off from the existing crystal structure and change to the more energetic liquid phase. As the temperature increases, the average kinetic energy (KE) of the solid substance increases and more particles would have enough energy to "escape" and become particles of the liquid phase. The same rationale can be made for liquid particles changing to the gaseous phase.



SPECIFIC LEARNING OUTCOMES

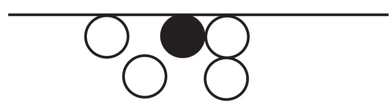
C11-1-05: Use the Kinetic Molecular Theory to explain the processes of evaporation and condensation.

Include: intermolecular forces, random motion, volatility, dynamic equilibrium

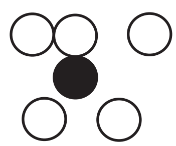
C11-1-06: Operationally define vapour pressure in terms of observable and measurable properties.

(continued)

Vaporization is the process by which a liquid changes to a gas or a vapour. When vaporization occurs only at the surface of a liquid, the process is called *evaporation*. If a sample of liquid is left open to the air, particles at the surface ● may collide with other particles and absorb enough kinetic energy to overcome the forces of attraction and change into the gaseous state. However, if a particle collides with an air particle above it, it may lose energy and become part of the liquid again (see diagram below).

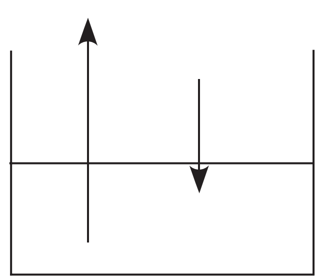


More particles and, therefore, generally greater forces of attraction surround a particle within the liquid, as shown in the following diagram.



If a particle within the liquid absorbs enough energy to change into a gaseous particle, it is more likely to collide with another liquid particle, lose energy, and return to the liquid state. This argument can be used to explain why evaporation is a surface phenomenon.

Simple experiments show that if the surface area is increased, the rate of evaporation increases. At the surface, two processes are occurring: a rate of evaporation and a rate of condensation as gaseous particles are "recaptured" by the liquid state. If a container of liquid is open, the rate of evaporation will usually exceed the rate of condensation and the level of the liquid will drop as liquid particles move into the gaseous state (see diagram below).



SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

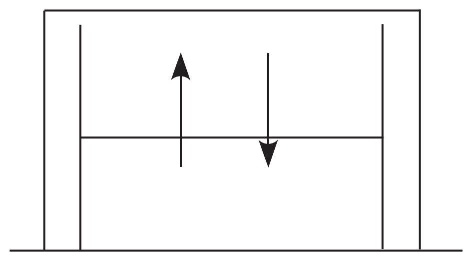
Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

However, if the container is closed, the rate of condensation will eventually equal the rate of evaporation and the level of the liquid will no longer change, if the temperature is kept constant. This is called a *dynamic equilibrium*.



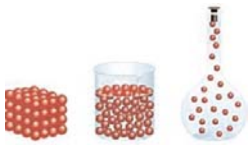
Class Discussion

Students could discuss responses to the following questions:

- What would happen if the temperature were changed?
- What would cause the level of liquid in an open container to stop dropping?
- Why do liquids evaporate at different rates?
- What would happen to either the open or closed system if a solid were dissolved in the liquid? (Extension activity)
- Predict what will happen if there are two containers with a solvent sealed inside them. One container contains a solute.

TEACHER NOTES

Remind students that when scientists talk about evaporation, vapours are inevitably mentioned. A *vapour* is the gaseous state of a substance that is normally liquid or solid at room temperature. Substances that evaporate rapidly are said to be volatile. They have lower intermolecular forces of attraction that hold particles into the liquid phase. Gasoline, paint thinner, alcohol, and dry-cleaning solvents are all volatile.



SPECIFIC LEARNING OUTCOMES

C11-1-05: Use the Kinetic Molecular Theory to explain the processes of evaporation and condensation.

Include: intermolecular forces, random motion, volatility, dynamic equilibrium

C11-1-06: Operationally define vapour pressure in terms of observable and measurable properties.

(continued)

Laboratory Activity

Have students measure the vapour pressure of a number of liquids (e.g., water, ethanol, methanol, 2-propanol, cyclohexane) at ≈ 20°C and 0°C. Ask students to share results and draw conclusions as a class. The experiment should show that vapour pressure is independent of the amount of liquid in the container. (See Appendix 1.10: Measuring the Vapour Pressure of a Liquid.)

Calculator-Based Laboratory (CBL) Activities

1. Vernier has an interesting experiment in which students measure the amount of energy required to evaporate a volatile liquid. By sampling a number of liquids, a relationship is established between the energy absorbed during evaporation and the intermolecular forces within the liquid. See *Chemistry with Calculators* (Holmquist and Volz—Vernier Software, Expt. 9.1).
2. Another lab (see Appendix 1.11: Forces between Particles) uses a pressure sensor and a temperature probe to measure the relative forces of attraction in a selection of volatile liquids.

Research Activity

Have student groups research the following topics:

- how the refrigerator, air conditioner, or dehumidifier works
- camp coolers
- vapour pressure of mercury and toxicity
- water vapour in the air

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

Research Reports

Student research could be reported or presented either individually or in small groups. The information collected could be presented as

- written reports
- oral presentations
- bulletin board displays
- multimedia presentations

Visual Displays

Students could present the material they have collected using

- posters
- pamphlets
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students prior to the assignment. Samples of presentation rubrics are provided in Appendix 10.

Laboratory Reports

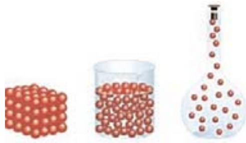
The vapour pressure lab activity could be assessed either as formal lab reports using the Laboratory Report Format (see *SYSTH* 14.12) or by using questions and answers from the data collected from the lab activity.

Paper-and-Pencil Tasks

Students should be able to answer questions that relate to the Kinetic Molecular Theory and phase changes. Several questions are included in the Suggestions for Instruction.

Journal Writing

The unusual discrepant events suggested for this learning outcome could be included as journal entries.



SPECIFIC LEARNING OUTCOMES

C11-1-05: Use the Kinetic Molecular Theory to explain the processes of evaporation and condensation.

Include: intermolecular forces, random motion, volatility, dynamic equilibrium

C11-1-06: Operationally define vapour pressure in terms of observable and measurable properties.

(continued)

LEARNING RESOURCES LINKS

Chemistry (Chang 463)

Chemistry (Zumdahl and Zumdahl 483)

Chemistry: The Central Science (Brown, *et al.* 425)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 356)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 428)

Chemistry with Calculators (Holmquist and Volz)—Available from Vernier: <http://www.vernier.com/chemistry/>

Chemistry with Computers (Holmquist and Volz)—Available from Vernier: <http://www.vernier.com/chemistry/>

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 406)

Glencoe Chemistry: Matter and Change: CBL Laboratory Manual – Teacher Edition (LAB 3: Melting and Freezing Points, 9)

Glencoe Chemistry: Matter and Change: Laboratory Manual – Teacher Edition

Introductory Chemistry: A Foundation (Zumdahl 408)

PASPort Explorations in Chemistry Lab Manual (PASCO Scientific)—Available from PASCO: <http://www.pasco.com/hsmanuals/ps2808.html>

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 428, 520)

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

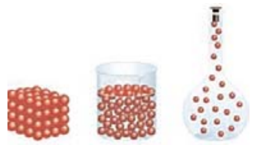
Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S2: State a testable hypothesis or prediction based on background data or on observed events.

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

NOTES



SPECIFIC LEARNING OUTCOME

C11-1-07: Operationally define normal boiling point temperature in terms of vapour pressure.

(0.5 hour)

SLO: C11-1-07

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

In Grade 7 Science, students were introduced to the concept that the boiling point of a pure substance is a characteristic property. No explanation was discussed. The learning outcomes in Topic 1 of Grade 11 Chemistry serve as an introduction to the *normal boiling point*.

Discrepant Events

It is not intended that all discrepant events be demonstrated. Select those appropriate for the class. Events 3 and 4 are not related to learning outcome C11-1-07 but are entertaining! These events could be used to address Boyle's Law (learning outcome C11-2-05).

1. This demonstration could be used to introduce boiling. After heating water (with boiling beads or chips) in a flat-bottomed flask to boiling, place a one-hole stopper with a thermometer in the flask and invert. Place a cold wet cloth on or pour cold water over the bottom of the flask. Have students observe and discuss the results. If a vacuum pump is available, the demonstration can be done at much lower temperatures. Remember to insert a $CaCl_2$ drying tube into the system before turning on the vacuum pump. **Caution:** Do not have students insert thermometers into stoppers.
2. Boil water in a kettle and have students observe the path of the steam. Place a lit candle just under the path of the steam. Have students observe and discuss the results.
3. If a vacuum pump and a bell jar are available, place marshmallows into the chamber and turn on the pump. Have students observe and explain what occurs.
4. If a large plastic syringe is available, the demonstration with marshmallows can still be done if the needle end is plugged.

General Learning Outcome Connections

GLO C6: Employ effective communication skills and use information technology to gather and share scientific and technological ideas and data.

GLO C8: Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO E4: Recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them.

SKILLS AND ATTITUDES OUTCOME

C11-0-U2: Demonstrate an understanding of chemical concepts.

Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives…

5. A similar demonstration can be done by placing a warm volatile liquid into the syringe and rapidly reducing the pressure. The liquid will begin to boil until the pressure is returned to normal. Have students operationally define boiling in terms of their observations of the preceding events.
6. Demonstrate "freezing by boiling." If cyclohexane is used in a syringe, the liquid will boil and then freeze. For complete instructions, see Appendix 1.12: Freezing by Boiling.

Laboratory Activity

If probeware and computer access is available, students can measure the effect of increased pressure on the boiling point of a liquid. For a full description of this lab activity, see Appendix: 1.13: Gas Laws: Temperature and Pressure Changes.

TEACHER NOTES

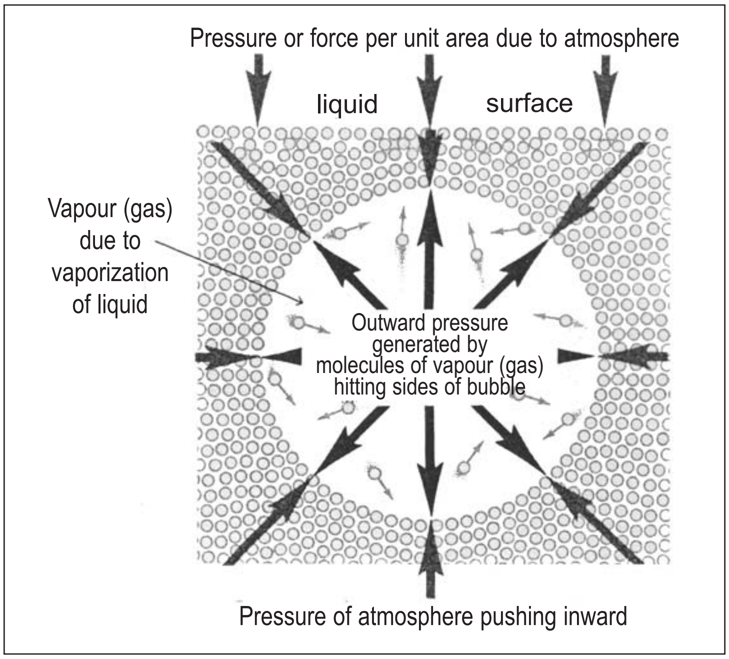
At low temperatures and low average kinetic energy, only the particles at the surface are able to evaporate into the gaseous state. As the temperature of the liquid increases, however, the number of particles having enough energy to overcome the intermolecular forces of attraction increases so that particles within the liquid are also able to change to gaseous particles. These gaseous particles form micro-bubbles within the liquid. If the vapour pressure of these micro-bubbles is less than the atmospheric pressure above the liquid, then the gas bubbles collapse and the particles within the bubbles return to the liquid state. However, if the vapour pressure of these micro-bubbles equals or exceeds the atmospheric pressure above the liquid, then the bubbles become larger and rise to the surface as the pressure on the bubbles become less.

As the temperature of the liquid increases, more micro-bubbles form because more particles have enough energy to change phase. The temperature at which the vapour pressure of the liquid equals the atmospheric pressure above the liquid is called the *boiling point*. *Normal boiling point* occurs when the atmospheric pressure above the liquid is standard pressure (1 atmosphere, 101.3 kilopascals [kPa], or 760 mm of mercury).

SPECIFIC LEARNING OUTCOMES

C11-1-07: Operationally define normal boiling point temperature in terms of vapour pressure.

(continued)



Bubble in a boiling liquid.

Figure: From *Chemistry: Experimental Foundations* by Robert W. Parry, Phyllis M. Dietz, Robert L. Tellefsen, & Luke E. Steiner © 1975 by Prentice Hall. Used by permission of Pearson Education, Inc.

Class Discussion

Wherever possible, have students use the Kinetic Molecular Theory in their explanations for the following discussions.

1. Compare the rates of evaporation for various liquids and correlate these with the vapour pressure and with the normal boiling temperature.
2. Discuss camp cooking at higher elevations.
3. Discuss the operation of a pressure cooker.
4. Predict the effect on boiling point of adding a solute, such as salt (learning outcome C11-4-11).

SKILLS AND ATTITUDES OUTCOME

C11-0-U2: Demonstrate an understanding of chemical concepts.

Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives…

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Visual Displays

Students could present their ideas of the boiling process visually in terms of particles. They could use the following to illustrate their ideas:

- posters
- pamphlets
- bulletin boards
- models
- multimedia

Paper-and-Pencil Tasks

Ask student to use the Kinetic Molecular Theory to

1. explain the process of boiling
2. explain how boiling would be affected by the addition of a solute to the liquid
3. explain how atmospheric pressure would affect boiling

Journal Writing

Have students reflect on the effect of reduced atmospheric pressure on boiling. Would mountaineers be able to boil water close to the top of Mount Everest?

LEARNING RESOURCES LINKS

Chemistry (Chang 464)

Chemistry (Zumdahl and Zumdahl 491)

Chemistry: The Central Science (Brown, *et al.* 425)

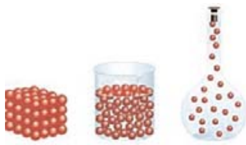
Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 358)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 428)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 406)

Introductory Chemistry: A Foundation (Zumdahl 400)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 483)



SPECIFIC LEARNING OUTCOME

C11-1-08: Interpolate and extrapolate the vapour pressure and boiling temperature of various substances from pressure versus temperature graphs.

(1.5 hours)

SLO: C11-1-08

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students may be familiar with the term *vapour*, but not in the context of the Kinetic Molecular Theory and vaporization. Other learning outcomes in Topic 1 of Grade 11 Chemistry have prepared students for learning outcome C11-1-08.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

This learning outcome provides students with an opportunity to apply the concepts they have learned in learning outcomes C11-1-05, C11-1-06, and C11-1-07.

The vapour pressure of a given liquid is inversely proportional to the strength of the intermolecular forces of attraction. The vapour pressure is also related to the average kinetic energy of the liquid. Students know that if the pressure above the liquid is decreased to the vapour pressure of the liquid at that temperature, the liquid will boil according to the operational definition of boiling. Students should then understand that liquids will boil at almost any temperature if the atmospheric pressure above the liquid is low enough.

Activities

1. Have students examine the following data table, Vapour Pressure of Some Liquids. Many chemistry texts provide similar data. If teachers prefer the data in kPa, the following conversion factor can be used:

   $$\text{mmHg} \times 0.133322\ \text{kPa/mmHg} = \text{kPa}$$

   $$\text{mmHg} \times 1.3579 \times 10^{3}\ \text{atm/mmHg} = \text{atm}$$

General Learning Outcome Connections

GLO A2: Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

GLO C2: Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

GLO E2: Describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems.

GLO E4: Recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U2: Demonstrate an understanding of chemical concepts.

Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives…

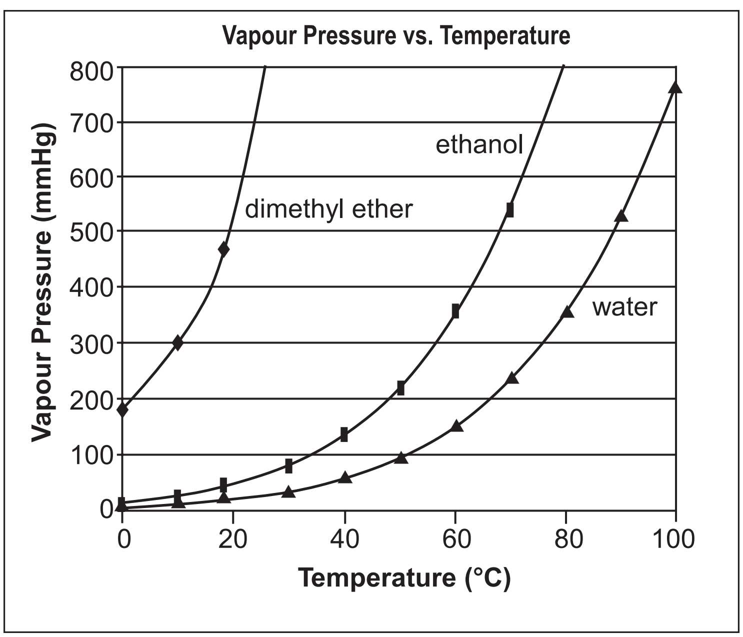
C11-0-S7: Interpret patterns and trends in data, and infer and explain relationships.

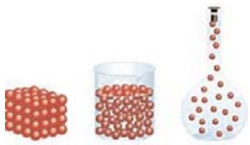
Vapour Pressures of Some Liquids

Temp. (°C)	Water (mmHg)	Ethyl Alcohol (mmHg)	Dimethyl Ether (mmHg)	Ethylene Glycol (mmHg)
0	5	12	175	
10	9	24	300	
20	18	44	450	
30	32	79	700	
40	55	135	1000	
50	93	222		
60	149	352		2
70	234	543		4
80	355	813		12
90	526	1187		24
100	760	1693		60

Reference: Parry, Robert W., *et al*. *Chemistry: Experimental Foundations*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1975. 106.

2. Ask students to graph the data either manually using metric graph paper or by using a graphing program. A sample plot appears below.





SPECIFIC LEARNING OUTCOME

C11-1-08: Interpolate and extrapolate the vapour pressure and boiling temperature of various substances from pressure versus temperature graphs.

(continued)

SUGGESTIONS FOR ASSESSMENT

Discussion Questions

The following are examples of questions for class discussion:

- What is the vapour pressure (VP) of ethyl alcohol at 40°C? (135 mmHg)
- Which substance would evaporate the slowest at 20°C? Explain your reasoning. (ethylene glycol—lowest VP at any temperature)
- Which substance has the least intermolecular forces of attraction? Explain your reasoning. (dimethyl ether—greatest VP at any temperature)
- List substances in increasing order of intermolecular forces. (dimethyl ether, ethanol, water, ethylene glycol)
- Which substance would have the least viscosity at 20°C? Explain your reasoning. (dimethyl ether—most volatile, least forces)
- Determine the atmospheric pressure required to have dimethyl ether boil at 20°C. (450 mmHg)

Topic-Review Activity

An activity game has been designed to review the material in Topic 1: Physical Properties of Matter. For details, see Appendix 1.14: Chemistry Is Super: “Bingo” Review Game.

LEARNING RESOURCES LINKS

Chemistry (Chang 464)

Chemistry (Zumdahl and Zumdahl 486)

Chemistry: The Central Science (Brown, *et al.* 425)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 428)

Skills and Attitudes Outcomes

C11-0-U2: Demonstrate an understanding of chemical concepts.

Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives…

C11-0-S7: Interpret patterns and trends in data, and infer and explain relationships.

Notes