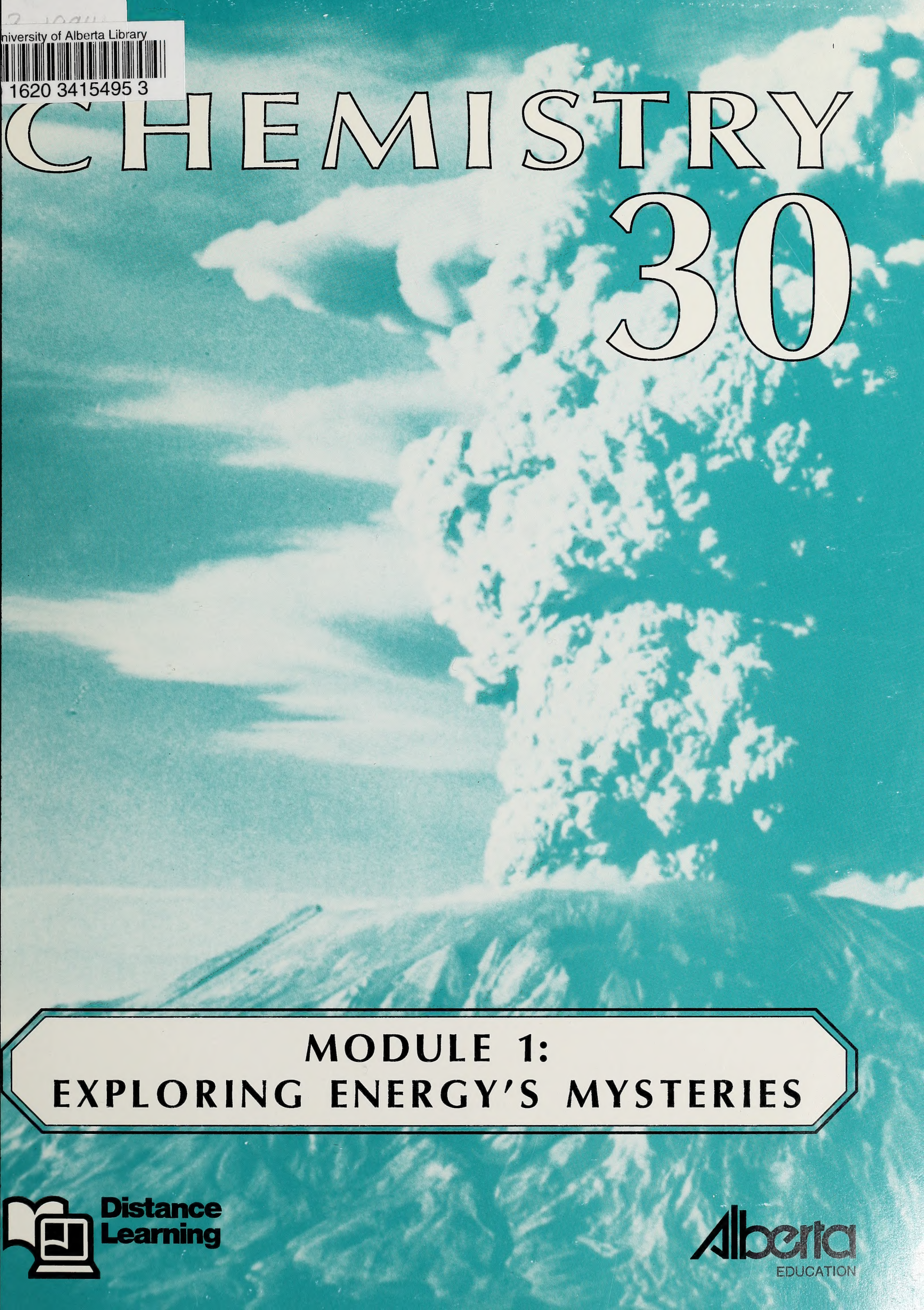
CHEMISTRY 30



MODULE 1:
EXPLORING ENERGY'S MYSTERIES

Distance Learning

Alberta
EDUCATION

Chemistry 30

Module 1

Exploring Energy's Mysteries

Distance Learning

Alberta
EDUCATION

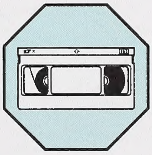
This document is intended for	
Students	✓
Teachers (Chemistry 30)	✓
Administrators	
Parents	
General Public	
Other	

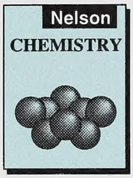
Chemistry 30
Student Module
Module 1
Exploring Energy's Mysteries
Alberta Distance Learning Centre
ISBN No. 0-7741-0901-7

Cover Photo: WESTFILE INC.

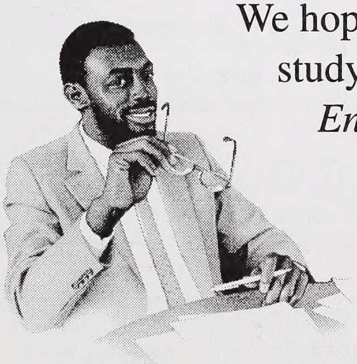
Welcome to Chemistry 30!

We hope you'll find this course interesting and fun. To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.





When you see this icon, study the appropriate pages in your textbook.



We hope you'll enjoy the study of *Exploring Energy's Mysteries* in this module.

Good Luck!

COURSE OVERVIEW

This course contains seven modules. The module you are working in is highlighted in deeper colour. It is recommended that you work through the modules in the order given since several concepts build on each other as you progress in the course.

CHEMISTRY 30

- [x] **Module 1** Exploring Energy's Mysteries
- [ ] **Module 2** Putting Energy to Work
- [ ] **Module 3** Electrochemistry – Give and Take
- [ ] **Module 4** The Practical Side of Redox
- [ ] **Module 5** Chemistry in Balance
- [ ] **Module 6** The Nature of Acids and Bases
- [ ] **Module 7** Acid-Base Applications

MODULE

1 Contents

MODULE 1

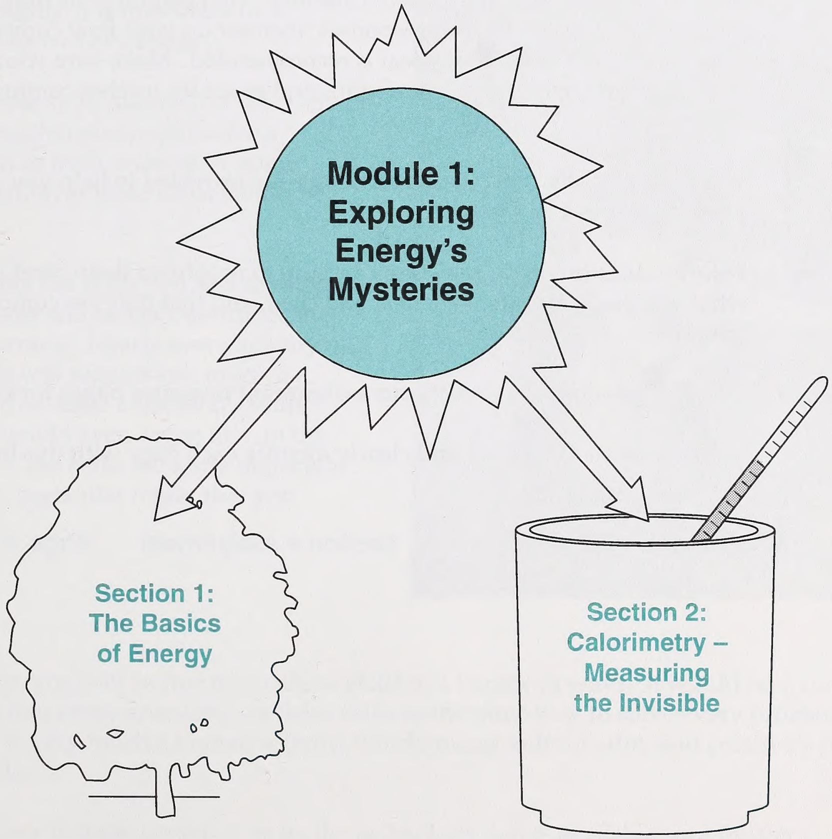
Contents

Continued

MODULE OVERVIEW

The sun has had an important role in ancient and modern societies. Scientists speculate about how long the sun will exist. Why is the sun so important to you? Your life centres around the sun. It is the single most important source of energy needed to sustain life on Earth. Society harnesses and uses the sun's energy in several forms. The food you eat, the fossil fuels you burn, and the solar energy trapped directly by solar cells are all forms of energy that originated from the sun.

To meet the challenge of society's ever increasing demands for energy, you need to use the energy resources efficiently. It is therefore essential to know the laws which govern energy changes. In this module you will explore the principles of thermochemistry, the part of chemistry that involves the study of energy changes.



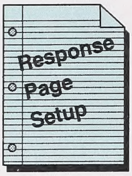
Evaluation

Your mark in this module will be determined by how well you complete the assignment at the end of each section. You must complete all assignments. In this module you are expected to complete three assignments. The mark distribution is as follows:

Section 1 Assignment	**35 marks**
Section 2 Assignment	**40 marks**
Final Module Assignment	**25 marks**
TOTAL	**100 marks**

When doing your assignments, work slowly and carefully. If you are having difficulties, go back and review the appropriate section.

Read all parts of your assignment carefully. Plan and do your rough work on your own paper. Revise and edit your responses; then set up your final copy for submission on your own paper. Lined looseleaf is recommended. Make sure your answers are neat and organized, with wide left margins and space for teacher comments after each assignment.



When you see this icon, ideas and details are provided to help you set up and organize your answer in a certain way.

Before submitting your responses, be sure to proofread them carefully to ensure they say what you want, that they are neat and clear, and that they are complete and missing no material.

You will be submitting **only** your **assignment response pages** for evaluation.

It is important to number and clearly identify each page with this information placed at the top.

Chemistry 30 – Module 1 Section # Assignment Page # Name and ID #

Science Skills

One of the exciting features of this course is that you will develop and improve your ability in the area of science skills. These skills include

- initiating and planning
- collecting and recording
- organizing and communicating
- analysing
- connecting, synthesizing, and integrating
- evaluating the process or outcomes

Although these skills are referred to as science skills, it is important to remember two key ideas.

First, these skills are not just for science. Any time that you might solve a problem or make a decision, some combination of these skills would be used.

Therefore, the skills you will develop in this course will be very useful for life-long learning. Nearly every activity of your life will require you to solve a problem or make a decision. Some people would even argue that, in the long run, the skills are more important than the particular topics that you study.

NASA

Secondly, you will be free to use these skills in a variety of ways. It would be wrong to assume that every scientist uses these skills in the same way to solve every problem. Science is very much a human activity, which means individuality and creativity play a large role.

The society that the person lives in, the technology that is available, and the very personality of the scientist will determine which skills are combined to create a solution to a problem.

It follows from this idea that the science that you do and the science skills that you prefer to use will be unique to you; and that's OK. It also follows that you likely will not be performing at the same level for all skills, which is a natural thing. In this course you will continually practise all of these skills and you will have an opportunity to assess your level of performance in each skill.

These science skills will be developed further in Activity 1 and explained in detail in the Appendix for this module.

NASA

Important Notes

- If you completed Chemistry 20 through distance learning, Activity 1 of this module will be familiar to you. You may choose to review the activity briefly to refresh your memory on science skills, then proceed to Activity 2.

  If you did not complete Chemistry 20 through distance learning, work through Activity 1 carefully as you would normally do.

- You will be required to write a Chemistry 30 Diploma Examination in addition to a distance learning final test after completing this course. Therefore, it is important for you to be familiar with the types of questions asked and the types of answers expected on a diploma exam. This course will give you various examples of diploma exam-type questions and instructions to enable you to be prepared fully for the final exam.

- You will be doing several investigations involving acids, bases, and other chemicals that could cause damage to a table surface. It is recommended that you perform your investigations on a plastic tablecloth or on some resistant surface. Also, make sure that you check the materials required for each investigation to see what substances or equipment must be supplied by you. A list of materials to be supplied by you is given in the Appendix of Module 7. You may wish to check your home inventory now to see what items you will need to purchase. **Please note:** The items in the list may, in certain cases, be substituted.

- There are no response lines included with the activity or assignment questions asked in the student module booklets of this course. This means that you will need to have paper on which to answer the questions handy at all times. It's probably a good idea if you keep your answer pages in a binder or folder. You will also require your textbook *Nelson Chemistry*, graph paper, and a calculator. Read all the questions carefully and answer them as completely as possible. Then check your answers in the Appendix. This will allow you to assess your growing abilities in this course.

- It is also important that you work through the section activities thoroughly before attempting the assignment questions. This will help you to achieve a greater degree of success in your studies.

Diploma Exam Preparation

Since you will be writing a Chemistry 30 Diploma Examination when you have finished this course, it's important that you are familiar with the types of questions that will be asked and the format in which they will be presented. From time to time, throughout the modules in this course, you may be given several activity questions and assignment questions of diploma exam format so that you can become familiar with these types of questions. For more detailed information on preparing for diploma exams, consult the Appendix in this module.

There are three basic types of questions you will encounter on a Chemistry 30 Diploma Examination:

- **Multiple Choice**: With each question you are given several (usually four) alternative answers, listed by A., B., C., and D. from which you choose the single **best** possible answer. Each multiple choice question is worth one mark. You record your choice for each question by letter on a separate answer sheet provided.

- **Written Response**: Written response questions are multiple-mark questions in which you are expected to show all your work and organize and present your answer in a clear and precise manner. Marks may be given for clarity in the communication of your answer as well as the shown calculation work. You will be given several activity and assignment questions of this question style.

- **Numerical Response**: A numerical response question is designed so that you must record your answer, but you do not show your work. There are two basic types of numerical response questions: calculation questions and correct-order questions. Whichever type, you will be expected to record your answer on the same type of machine-scored answer sheet. Two samples are as follows:

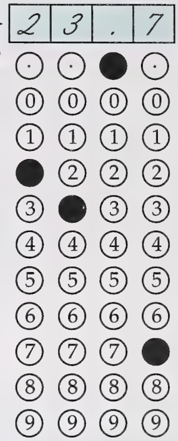
Sample Calculation Question and Solution

The mass in grams of silver produced when 0.220 mol of silver nitrate reacts with excess copper is ________ g.
(Record your answer to three digits.)

$$\begin{aligned} \text{mass}_{Ag} &= 0.220 \text{ mol} \times 107.87 \text{ g/mol} \\ &= 23.7314 \text{ g} \\ &= 23.7 \text{ g (rounded to three digits)} \end{aligned}$$

Record 23.7 on the answer sheet

Notice that the decimal in the calculated value uses one of the four spaces in the answer box.



Sample Correct-order Question and Solution

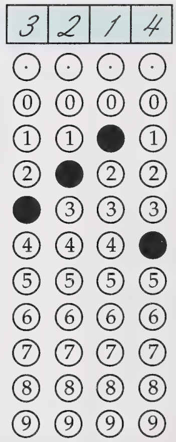
When the following subjects are arranged in alphabetical order, the order is ________. (Record all four digits.)

1. mathematics
2. chemistry
3. biology
4. physics

Answer 3, 2, 1, 4

Record 3214 on the answer sheet

This is the way you would "bubble" in your answer on a diploma exam.



For practising this type of question, you may be asked in an assignment question, for example, to place your response in a four-place box similar to the following:

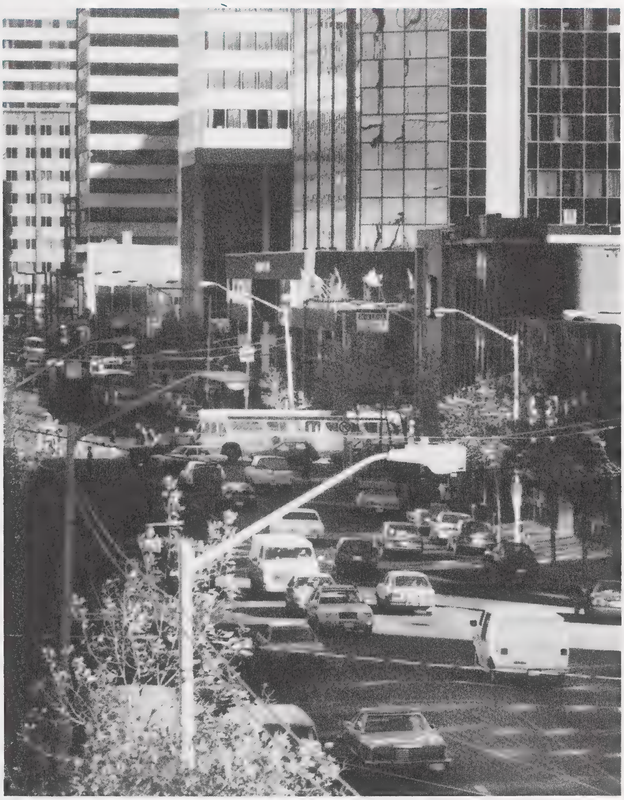
This is just to get you used to answering these questions in the correct way. Notice that this is the same box used on the top of the sample answer sheets shown previously. Each numerical response question is worth one mark.

SECTION 1

The Basics of Energy

Can you imagine what it would be like to have no gasoline to run cars or no energy to generate electricity? Modern society needs large amounts of energy for daily use. Most of it comes from various fuels. This energy is put to different uses in different forms. How do you transfer one form of energy to another for it to be more useful?

Energy is something you know exists, but have you ever seen energy itself besides light energy? Or have you seen only its effects? In order to more fully understand energy, it is important to have ways of measuring and describing the invisible phenomenon.



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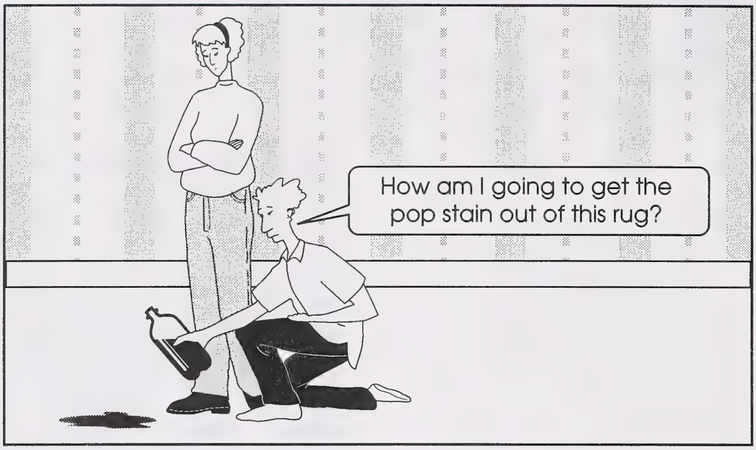
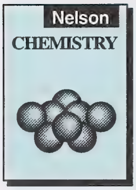
In this section, you will first review the scientific method and analyse the importance of science skills. Then you will learn about different forms of energy and how energy can be changed from one form to another by energy converters. You will apply the principle of heat flow to find the amount of energy change involved in different types of systems. As well, you will discover several methods of communicating information about energy changes.

ACTIVITY

1 Your Growth in Science Skills



science skills – processes and their component skills required to obtain a solution to a particular problem



Has this ever happened to you? You are not concentrating as much as you should and, all of a sudden, oops! Spilled pop on the carpet! Now what are you going to do?

You have probably run into many problems in your life, like spilled pop, where you've had to come up with a solution. Many of your solutions, even though you may not have realized it, probably had a scientific or systematic basis.

In this activity, you will focus on several scientific problem-solving skills in the investigations you examine. The background that you develop in science skills now will help you later in other module activities. For an introduction to science skills and problem solving, read the bottom paragraph of page 17 and the top half of page 18 in your textbook.

Special Note

Remember that whenever you answer questions in this course, your responses will be written on separate paper. Keep some paper handy at all times. Answer all questions carefully.

1. In the progress of scientific problem solving, what steps do scientists go through?

2. How do scientists evaluate the scientific problem-solving process?

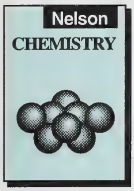
Check your answers by turning to the Appendix, Section 1: Activity 1.

You are still probably wondering how to solve the problem of the spilled pop. The following sample investigation will allow you to solve this problem. You will also familiarize yourself with these concepts:

- the problem solving approach used in the investigations you will do in this course
- the science skills you will use in the course

Further information on the problem solving model can be found in Appendix B (page 522) of *Nelson Chemistry*.

Investigation 1.1: Stain Removal



Work through the sample investigation on pages 18, 19, and 20 of your textbook. It is not necessary that you actually perform this investigation, as long as you get a clear understanding of how each step in an investigation should be developed. However, you can certainly perform the investigation if you wish.

Please note the following as you study the investigation:

- the steps of the investigation (problem, prediction, experimental design, etc.) and how these steps are performed

- the types of variables involved

- the safety symbols used

- the method the textbook will use in each investigation to tell you which steps you need to do

Answer the following questions when you have finished.

3. What is the difference between the purpose and the problem of an investigation?

4. Describe the difference between an experimental design and a procedure of an investigation.

5. Part of the experimental design involves the identification of variables.

   a. Construct a table similar to the following and fill in the required information. You may find the information given in Table 1.4 on page 31 of your textbook helpful.

Type of Variable	Definition
manipulated	

   b. Use a table to list the manipulated, responding, and possible controlled variables for the stain removal investigation.

6. How does the evidence step differ from the analysis?

7. In the investigation icon found in the textbook margin, how are the steps to be performed indicated?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The following chart illustrates the relationship between the textbook investigation steps and science skills.

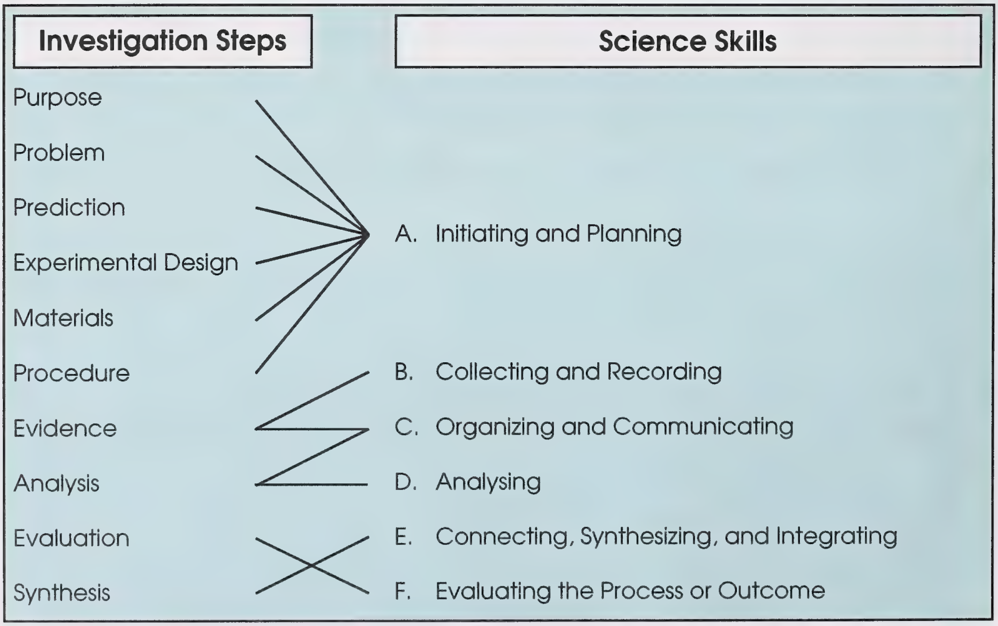


FIGURE 1.1: The Science Process

You may recall that the science skills were discussed briefly in the introductory pages of this module. They are described more fully in the module Appendix. Figure 1.1 will be very valuable to you in the understanding of what is involved in each science skill you will be using.

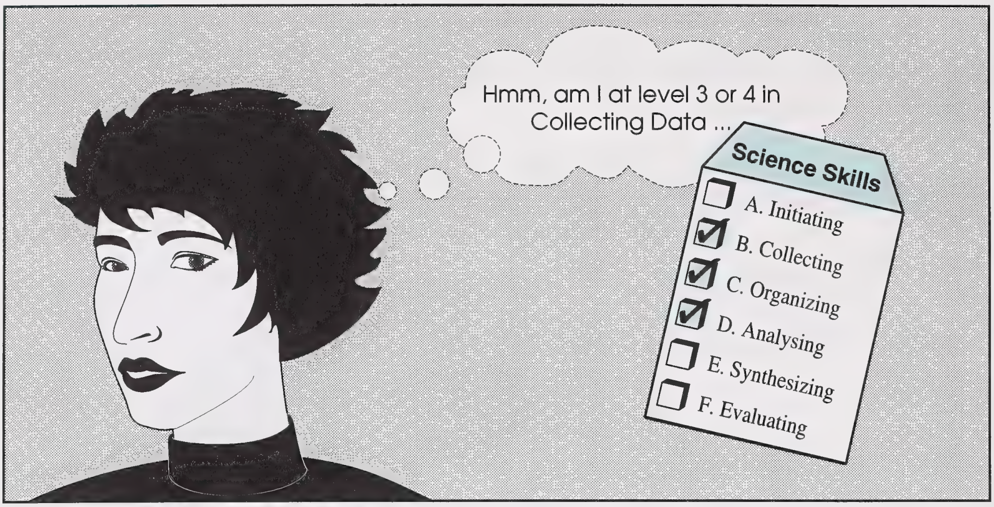
As you complete this course you will be continually practising the skills of science. You will be asked to assess your ability and you will receive feedback on your progress. The whole purpose of this process is so that you can improve and grow in your abilities.

In order to inform you of suitable opportunities to assess your skills, a science skills icon will be used in the margin throughout the modules. The specific skills being practised will be indicated by checkmarks.

Full Science Skills Titles

Besides doing your own assessment of your science skills, a teacher will also assess your science skills.

The method used to assess your ability in each of these skills involves using a **level** of performance. There are five possible levels. Level 5 is the top level of performance. It describes work that would be done of a college or university calibre. Since you are still a high school student it is reasonable to assume that you will likely be operating at levels 2, 3, or 4 in most of the skills. Note that it is natural to be performing at different levels for different science skills.



To familiarize yourself with the differences between each of these levels, read the descriptions for each level as they are applied to each of the six science skills. The descriptions can be found in the beginning of the Appendix to this module.

To gain practice in assessing levels in science skills, perform the following investigation.

Investigation: Aluminum in Copper(II) Chloride

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Whenever you do an investigation or other aspects of this course involving science skills, examine the science skills icon in the margin.

In this investigation, the icon indicates that you will be concentrating on the skills of collecting and recording (B. Collecting), organizing and communicating (C. Organizing), and analysing (D. Analysing).

Carefully follow the directions given for this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

qualitative – observations of what is present, made without measurements

quantitative – observations of what is present, made with measurements

The purpose of this investigation is to make qualitative and quantitative observations when a piece of aluminum foil is mixed into a solution of copper(II) chloride.

Materials

- aluminum foil
- copper(II) chloride dihydrate
- distilled water
- 250 mL beaker
- stirring rod
- thermometer

Procedure

Caution

Note: Wear goggles during this investigation.

- Cut a 10 cm × 10 cm piece of aluminum foil.
- Measure about 5 g (5 mL or 1 tsp.) of copper(II) chloride dihydrate, $CuCl_2 \bullet 2H_2O$.
- Pour about 100 mL of distilled water into a 250 mL beaker.
- Slowly and carefully add the copper(II) chloride dihydrate to the water without stirring. Observe.
- Dissolve the copper(II) chloride dihydrate in the water by stirring. Observe.
- Crumple the piece of aluminum foil into a loose ball (about 2 cm diameter).
- Place the aluminum foil into the $CuCl_{2(aq)}$ solution.
- Carefully push the aluminum ball down into the solution with the thermometer, noting observations and temperature readings.
- Dispose of solid waste in the garbage. Liquid waste can be poured down the sink.

8. Complete the evidence for the investigation by organizing and recording your observations in a table on a separate sheet of paper.

If you have access to the laser videodisc *The Chemistry Disc: Exothermic and Endothermic Reactions*, view the sequence that starts with frame 01687. This gives you another example of the reaction in the investigation.

Title

Frame 01685

Reaction

Frames 01687-03608

If your laser videodisc player does not have a bar code reader, use the frame numbers provided with the bar code icon to search for and then play each sequence.

Analysis

Complete the analysis for the investigation by doing the following questions.

9. Based on your observations, was this reaction exothermic (heat is released) or endothermic (heat is absorbed)? Explain how you know.

10. What was the orange-red solid on the surface of the aluminum foil?

11. Identify two pieces of evidence that indicate a chemical change occurred.

Check your answers by turning to the Appendix, Section 1: Activity 1.

12. Based on the skills information given in the Appendix, and your own assessment abilities, write your assessment for each of the following sample evidence tables. Assess both collecting and recording (B.), as well as organizing and communicating (C.) skills.

EXAMPLE EVIDENCE TABLE 1

Substance	Observations
aluminum foil	The silver solid turned red when put into the beaker. Rust was formed.
copper chloride solution	The blue solution bubbled when the foil was put in.

Example Table 1: B. Collecting – level ☐ C. Organizing – level ☐

EXAMPLE EVIDENCE TABLE 2

Substance	Observations
aluminum foil	Before the reaction the 10 cm × 10 cm foil was silvery in colour.
copper(II) chloride	Before the reaction the copper(II) chloride was a blue solid weighing 5 g.
water	The water was a clear liquid before the reaction.
aluminum foil in solution	The aluminum foil started to smoke when it was placed in the solution. A reddish-brown solid appeared on the foil's surface.
copper(II) chloride solution	When the foil was added, the solution started to bubble around the edges of the foil and steam rose up.

Example Table 2: B. Collecting – level ☐ C. Organizing – level ☐

EXAMPLE EVIDENCE TABLE 3

Before placing the aluminum foil into the solution –

Substance	Observations	
	Quantitative	Qualitative
aluminum foil	10 cm × 10 cm 0.5 g	silvery solid, shiny in appearance
copper(II) chloride	5 g (5 mL or 1 tsp.)	blue granular solid, dull appearance; when placed in water – initially was green but when dissolved, turned blue
water	23.5°C 100 mL	clear, colourless liquid

After placing the aluminum foil into the solution –

Substance	Observations
aluminum foil	10 s – The aluminum foil appeared to be releasing steam when mixed in the $CuCl_{2(aq)}$. 20 s – Small patches of reddish-orange solid appeared on the surface. – Some small patches of black solid appeared. 50 s – The surface of the foil was almost entirely covered with red solid. – There were still a few patches of black and silver colour.
copper(II) chloride solution	10 s – Steam starts to appear to rise from solution; there are bubbles. 20 s – There is more bubbling of solution around edges of foil; temperature has risen to 25.5°C. 250 s – There is fairly vigorous bubbling around the edges of foil; solution has increased to 41.8°C.

Example Table 2: B. Collecting – level ☐ C. Organizing – level ☐

Check your answers by turning to the Appendix, Section 1: Activity 1.

If the previous investigation had been one of your assignment questions, the level of your performance in the three science skill categories that were focussed on would be assessed. Both you and a teacher would assess the response level.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

The question would have a science skills icon like the one shown in the margin. The skills to be evaluated would be checked.

Then once you completed your answer for the question, you would reproduce a science skills assessment box. This is where you and your teacher would each write evaluatons of your skill level for each identified science skill. The box would look like the following:

Self:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

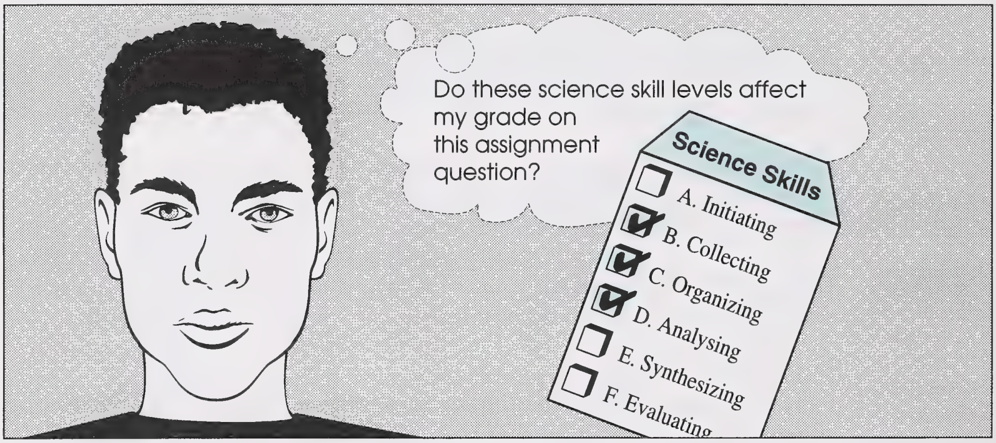
As an example, you may have thought that your skill level in the skills indicated by boxes B, C, and D were at levels 4 and 3 for the previous investigation. You reproduce the skills box as follows at the end of your response to the assessed question.

Self:	A. ☐	B. 4	C. 4	D. 3	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

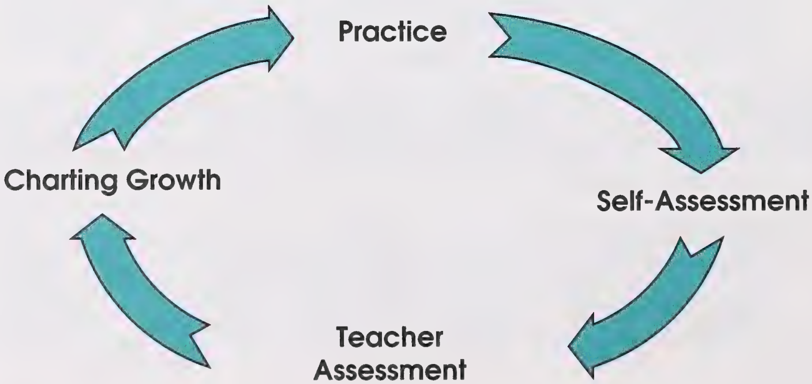
You then hand in the completed response page to be marked. When the assignment is returned, the teacher assessment of your skill level of performance is as shown:

	A.	B.	C.	D.	E.	F.
Self:		4	4	3		
Teacher:		3	4	3		

The teacher assessed your science skills in collecting and recording data one level lower than you did, but the other two skills were assessed the same. What does this mean? It means that the teacher probably thought you could have been more complete in your observations than you thought. It is important for you to realize that this teacher skill level assessment should NOT be interpreted as part of your grade. Rather, it is valuable feedback to help you to know the areas where you need to improve.



Everyone can improve his or her science skill abilities. Therefore, to help you improve and grow in your abilities with these skills, a strategy has been developed for this course.



13. a. Where will you practise improving your skills?

    b. When will you know it is time to practise using your science skills?

    c. How will you know what skills you are practising?

14. How will you know when your science skills are being assessed in the assignment questions?

15. Will the level assessment of your skills affect your grade on the particular assignment question?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The whole purpose of identifying skills with the margin icons is to increase your awareness of, and growth in, each of the science skill categories. As seen in the previous example, your self-assessment may be the same, or different, than your teacher's assessment in these science skills. The important thing is that you gain practice and are able to improve in the skills themselves and in your ability to assess your own skill level.

Feedback from the assessment (both self and teacher) of your science skills is valuable and needs to be charted over time. As you progress through the course you will be practising the same skills throughout each module. To keep track of your progress and growth, you will record your self-assessment and teacher assessment on a spreadsheet similar to the one located in the appendix of this module (this allows you easy reference to the skills level information charts). This sheet may be photocopied or reproduced and is to be handed in with the last assignment of the course (in Module 7). You may wish to make a copy of the spreadsheet at this time and keep it posted for handy reference, or you may keep a copy at the start of your Chemistry notebook.

16. Where do you find more information on the science skills and levels?

17. What is the purpose of keeping track of your level of skill performance?

18. Turn to the Appendix and find the sample spreadsheet for recording the assessment of process skills.

    a. When your assignments are returned, what two assessments do you record on the spreadsheet?

    b. What is the advantage of recording **all** the assessments, from the whole course, on one spreadsheet?

Check your answers by turning to the Appendix, Section 1: Activity 1.

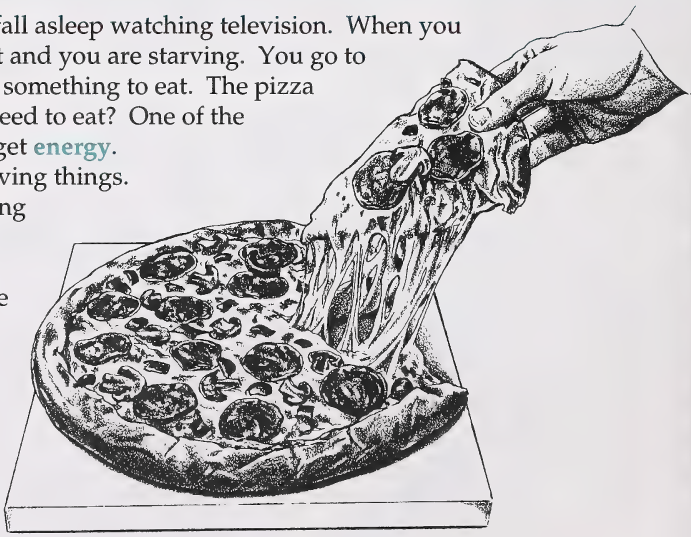
As mentioned at the beginning of this activity, the science skills you develop and improve upon now will not only benefit you in your further science studies. These skills will be with you for any problems you tackle in life, in general.

ACTIVITY

2 Energy Forms and Heat

energy – the ability to do work

You come home tired and fall asleep watching television. When you wake up it is past midnight and you are starving. You go to the refrigerator looking for something to eat. The pizza looks good. Why do you need to eat? One of the main reasons you eat is to get **energy**. Energy is essential for all living things. It can be obtained by burning fuels. The fuel used by the human body is food. The fuel used by cars is gasoline which is obtained from crude oil. In both cases energy is stored in the chemical bonds of the molecules making the fuel.



The following graphic shows the process of obtaining energy from the food you eat.

ATP (adenosine triphosphate) – an organic molecule which stores energy in living things

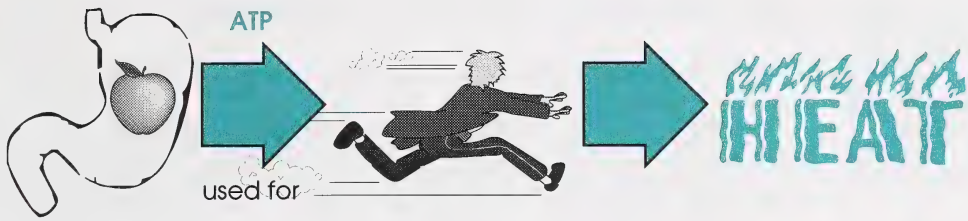


FIGURE 1.2: Energy Changes

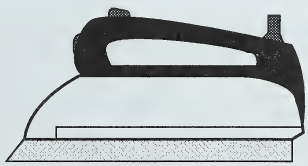
1. List three forms of energy that Figure 1.2 illustrates.

Check your answers by turning to the Appendix, Section 1: Activity 2.

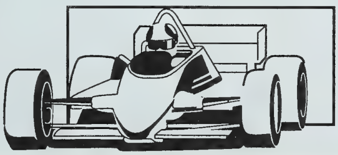
In your answer for the preceding question, you described several different forms of energy. There is one factor common to all these forms – they all involve doing work. As you have seen and experienced, energy can be converted from one form to another.

Telephones change **sound** energy into **electrical** energy

... and **electrical** energy into **sound** energy.

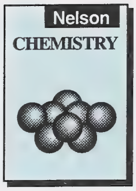


An iron changes **electrical** energy into **heat** energy.



Brakes change **kinetic** energy into **heat** energy.

You can see that most forms of energy are ultimately changed to heat, as shown in the preceding examples. When an airplane lands, its tires lose a great deal of energy in the form of heat when they undergo frictional forces. In fact, this helps (in a small way) reduce the speed of the airplane.

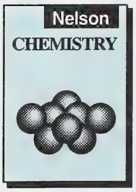


To learn more about how energy is classified, read page 285 of your textbook.

2. Answer textbook questions 1 to 5 on page 286 of *Nelson Chemistry*.

Check your answers by turning to the Appendix, Section 1: Activity 2.

thermal – changes related to heat energy

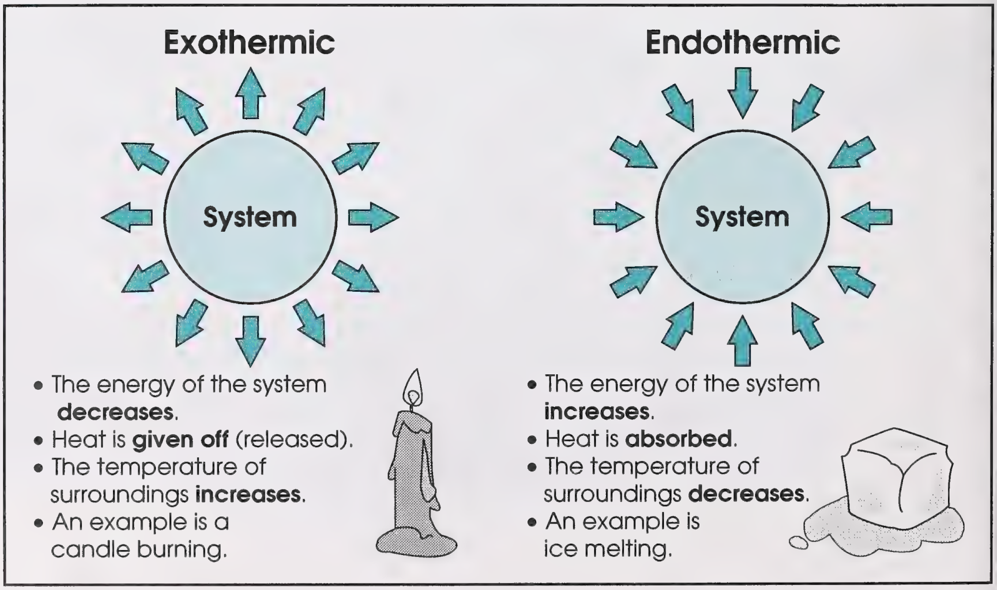


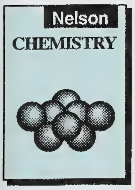
Chemical reactions involve thermal changes. Consider the case of sugar burning (being oxidized) in your body to give energy. Sugar in a jar in the kitchen does not burn; once in the body it is *burned* or reacted slowly by catalysts in your body to produce energy, some of which is then lost in the form of heat. For every gram of sugar burned, approximately 16.5 kJ of heat energy are released. How do you know that energy is given off? If heat energy is being radiated by your body, then the temperature of the surroundings must go up. This is what in fact occurs. An example of a thermogram illustrating this effect can be seen on page 286 of your textbook. Similarly, some systems absorb heat. Snow on mountains absorbs energy, especially in the spring and summer. How do you know the snow absorbs energy?

thermogram – an infrared picture which shows different levels of heat energy

systems – groups of units working as a whole

Energy changes in systems which result in heat energy being given off are called exothermic and those energy changes which result in systems absorbing heat energy are called endothermic.





Read the section titled Heat on page 286 and the top of page 287 of your textbook to learn more about endothermic and exothermic changes.

3. Classify each of the following changes as endothermic or exothermic.

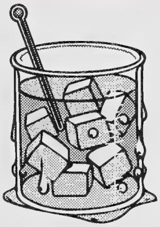
   a. Moisture in the air changes to snow.

   b. Water vapour from the car exhaust condenses to form water.

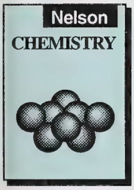
   c. Plants use solar energy to synthesize food.

   d. Water evaporates from the surface of the lakes.

Check your answers by turning to the Appendix, Section 1: Activity 2.



Besides knowing whether energy is flowing into or out of the system, it is also essential for you to know the magnitude of the change involved. Kinetic energy changes are often associated with temperature changes. Heat and temperature are not the same quantities however.



Read the first paragraph on page 287 of your textbook. Pay special attention to the margin notes to find the difference between temperature and heat. As well, refer to page 93 to get information on kinetic energy.

4. Explain the behaviour of smoke using the kinetic molecular theory.

5. In a table, state the difference between temperature, kinetic energy, and heat.

Temperature	Kinetic Energy	Heat

6. List the words necessary to fill in the following blanks.

   A change in the ____________ of a substance, as measured by a thermometer, is associated with a change in the average ____________ ____________, ____________, of the particles in the substance.

7. Reproduce the following symbol and label the appropriate parts.

$$\Delta E_k$$

Check your answers by turning to the Appendix, Section 1: Activity 2.

In your experience, do all substances heat and cool the same way? Different substances absorb and release heat at different rates so their kinetic energy is different over the same period of time. Since temperature is a measure of the average kinetic energy of a substance, this means that substances have different temperature changes when the same amount of heat is given to equal amounts of different substances.

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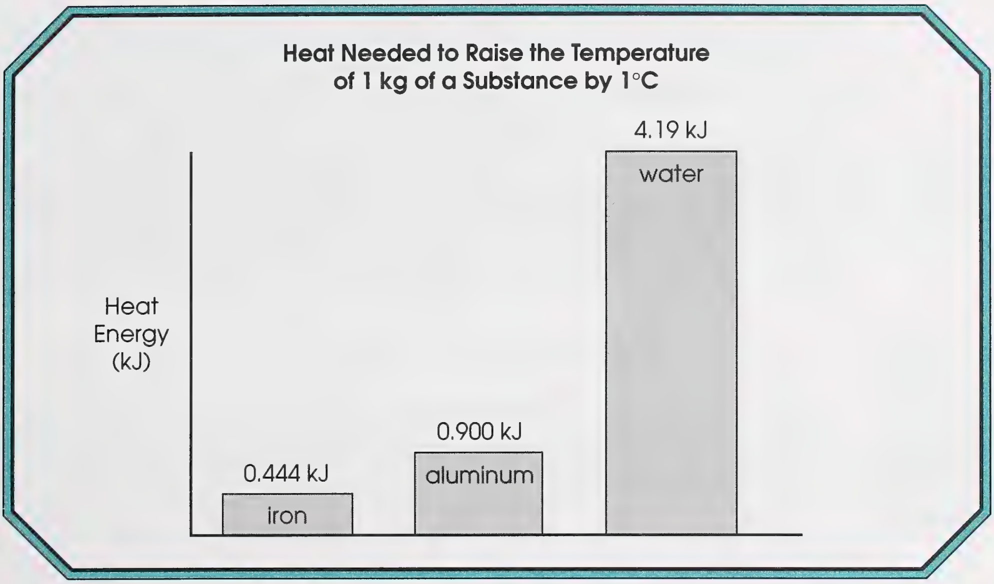
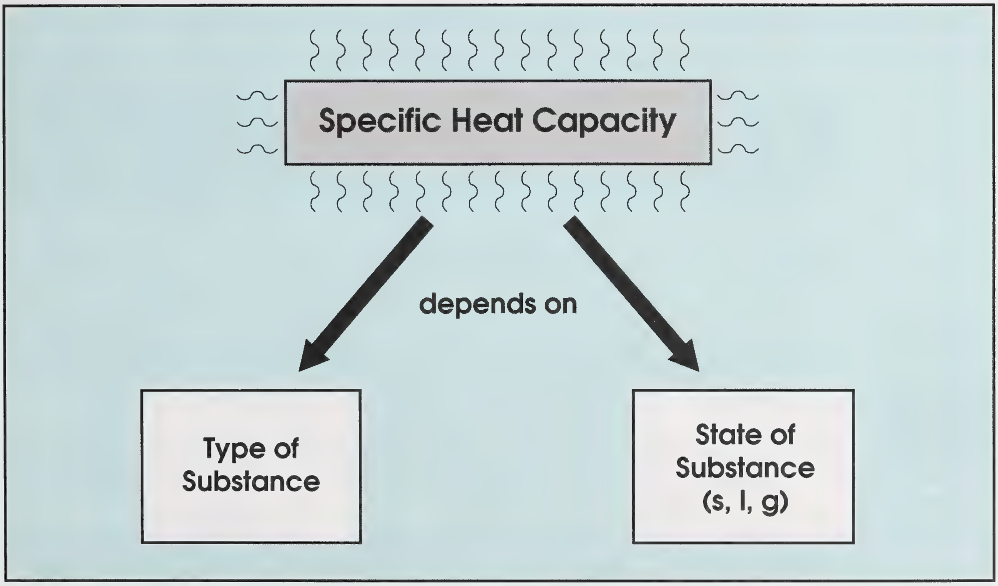
specific heat capacity – amount of heat needed to raise the temperature of a unit mass of substance by one degree Celcius

Have you ever wandered along the beach on a cool evening and noticed that the water felt especially warm to the touch? Can you explain why? It takes more energy to heat or cool water than it does air, so water will trap more heat after a warm day than will an equal amount of air. The concept behind this phenomenon relates to the specific heat capacity of the air and water. Because of a high specific heat capacity, water takes much longer to warm or cool than the surrounding air; the water in the evening, therefore, feels warmer than the air.

The following bar graph will give you some idea about how the specific heat capacity of water compares to some other substances.



What other factor do you think would affect the specific heat capacity of different substances? The specific heat capacity depends upon the physical state of the matter as well as the type of substance.



Nelson CHEMISTRY

Read the remainder of page 287 and all of page 288 in your textbook to learn more about specific heat capacity. Also study the example showing a sample energy calculation given on page 288.

Note: Your textbook describes two methods of calculating heat transfer,

$$q = mc\Delta t \text{ and } q = vc\Delta t.$$

To avoid possible confusion, in this course you will only be using the value for specific heat capacity, not volumetric heat capacity. An exception would be if volume is specifically asked for as a variable. This means that you will use $q = mc\Delta t$, which will require that you convert any liquid volumes to mass. For example, if 100 mL of water are involved in a calculation, you will convert the 100 mL value to 100 g or 0.100 kg (remembering that the density of water is 1 g/mL) to do the calculation.

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8. Answer textbook questions 6 to 13 on pages 288 and 289 of *Nelson Chemistry*.

Check your answers by turning to the Appendix, Section 1: Activity 2.

Some of the preceding questions you answered demonstrated how energy transfer and heat calculations can be associated with the functioning of a water heater in your home. The following investigation will allow you to use your new-found knowledge as you design a water heater.

Investigation 10.1: Designing and Evaluating a Water Heater

PATHWAYS

If you have access to supervised laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.

Part A

Nelson CHEMISTRY

Carefully read the description of Investigation 10.1 on page 289 of your textbook. Pay special attention to the required components, safety aspects, and applied science skills.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

Guidelines

- Pay special attention to the terms *specific energy* and *cooling rate* mentioned in the first paragraph in the investigation.
- Your design should be such that when you heat the water in the heater, the insulating material will not be in direct contact with the heat source.
- For a heating source do not use an open flame like that of a bunsen burner. Use a hot plate.

Caution

- Have your teacher check your design and the evidence table before you start the experiment.

9. Write a description of your water heater design, including a labelled diagram.

Check your answers by turning to the Appendix, Section 1: Activity 2.

10. Prepare an evidence table to record your measurements.

11. Follow the procedure and record your observations.

Complete your analysis by doing the questions after Part B.

Check your answers by turning to the Appendix, Section 1: Activity 2.

End of Part A

Part B

Nelson CHEMISTRY

Carefully read Investigation 10.1: Designing and Evaluating a Water Heater on page 289 of *Nelson Chemistry*. Pay special attention to the required components, safety aspects, and applied science skills.

Guidelines

Science Skills

- ☑ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

- Pay special attention to the terms *specific energy* and *cooling rate* mentioned in the first paragraph of the investigation.
- Because of the inherent dangers of heating the constructed apparatus at home, you will not actually perform the investigation; instead, you will obtain the evidence you need from the module Appendix.

12. Write a description of your water heater design, including a labelled diagram. Check your design by referring to question 9, Section 1: Activity 2 in the Appendix.

13. Prepare an evidence table and obtain the evidence from the Appendix, question 11, Section 1: Activity 1.

Check your answers by turning to the Appendix, Section 1: Activity 2.

As your analysis do the following questions.

End of Part B

14. To complete the analysis, calculate the specific energy and the cooling rate of your water heater. Show all your calculations.

15. Evaluate your water heater using the guidelines given in the investigation.

Check your answers by turning to the Appendix, Section 1: Activity 2.

You have already noticed that energy is an entity that can't be seen, but can be measured through its changes. You have learned that energy comes in different forms. You have also seen that some systems undergo endothermic energy changes and others undergo exothermic energy changes. In the next activity you will learn how to represent **enthalpy changes** using graphs.

enthalpy changes – changes in the total heat content of a system

ACTIVITY

3 Enthalpy and Systems

When a dance company works out in the gym, there are several forms of energy changes involved.

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1. Look at the preceding photograph. What are the various forms of energy changes occurring?

The different body movements create many chemical energy changes. The dancers slowly heat up because part of the chemical energy is changed into heat energy.

Nelson CHEMISTRY

Has the total energy of the system shown in the preceding photograph changed? To answer this question you first need to understand what the terms *open system* and *closed system* mean. Read the first paragraph on page 290 of your textbook, and then answer the following questions.

2. a. What would you identify as the system in the previous dance photograph example? Is it a closed system? Explain.

   b. Is there an enthalpy change in the system you described? Explain.

3. What symbol is used to represent enthalpy change?

4. What two quantities determine the total enthalpy of this system?

Check your answers by turning to the Appendix, Section 1: Activity 3.

As you have read, enthalpy changes in systems are reflected by energy changes in the surroundings. What types of enthalpy changes are there?

Nelson CHEMISTRY

To discover the first type of enthalpy change you will study, read from the second paragraph on page 290 to the middle of page 291 in your textbook.

5. a. What is a phase change?

   b. Give two examples of a phase change, other than the ones given in your textbook.

6. There are three endothermic phase changes. Give their names and write a brief explanation of each in terms of the kinetic molecular theory.

7. What is a heating curve?

8. a. Construct a table similar to the following to record your answer to this question.

Section	Potential Energy	Kinetic Energy	Temperature
AB			
BC			
CD			
DE			
EF			

For each section (AB, BC, etc.) in the following graph (Figure 1.3), indicate in your table whether there is an increase, decrease, or no change in each factor.

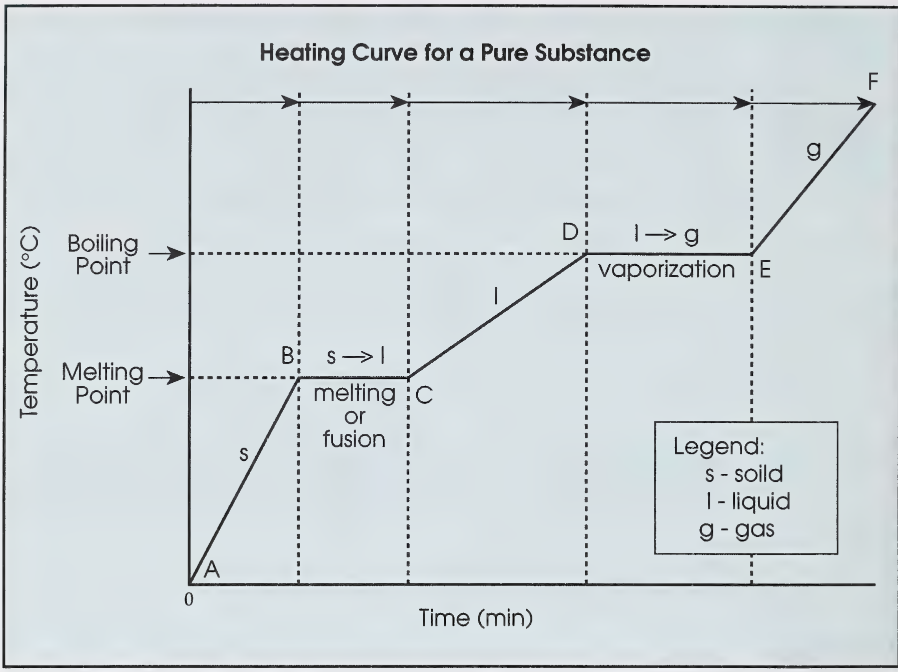
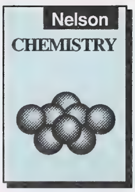


FIGURE 1.3: Heating Curve Graph

b. Which sections in the graph represent the energy changes occurring during phase changes?

Check your answers by turning to the Appendix, Section 1: Activity 3.



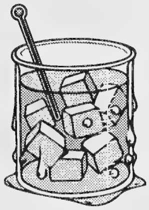
Chemical and nuclear changes also represent enthalpy changes. Read the section on chemical and nuclear changes starting from the middle of page 291 to the end of Table 10.2 on page 292 of your textbook.

9. What is the difference between a chemical change and a phase change in terms of the bonds that are broken and formed?

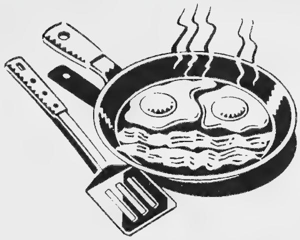
10. How does the amount of potential energy of a system change during an endothermic chemical change and an exothermic chemical change?

11. What type of bonds break during a nuclear reaction?

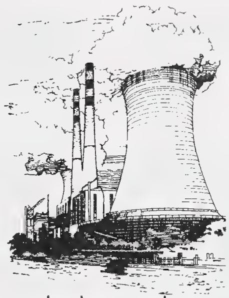
12. Consider the following systems involving enthalpy changes. What would be the order of these systems in terms of decreasing amount of enthalpy change?



a. melting ice



b. cooking eggs



c. producing nuclear power

Check your answers by turning to the Appendix, Section 1: Activity 3.

The following bar graph gives you some idea about the relative amounts of energy involved in the three types of enthalpy changes you have examined.

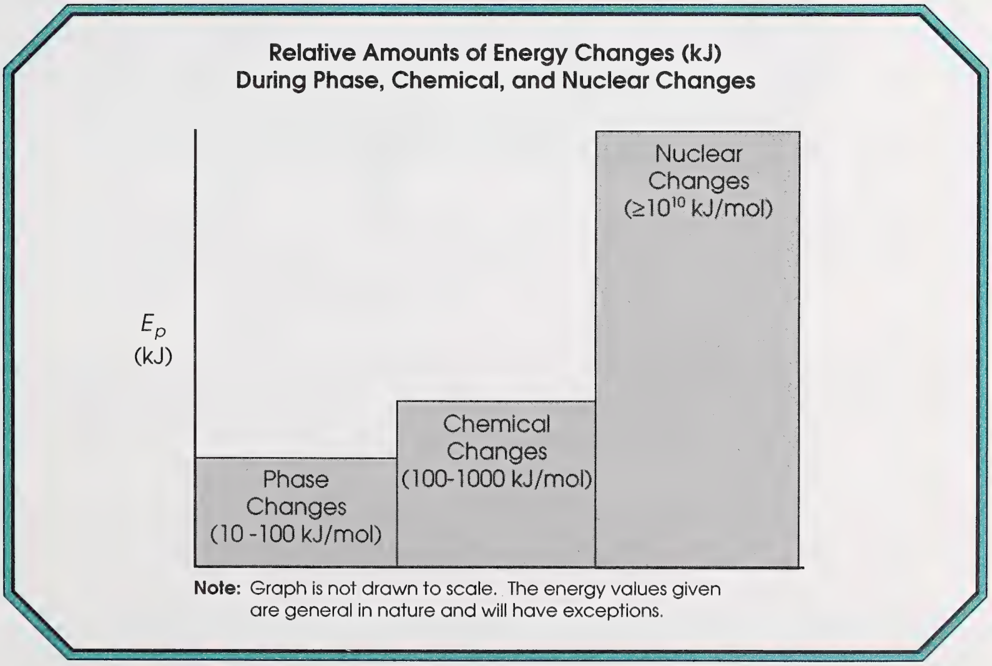
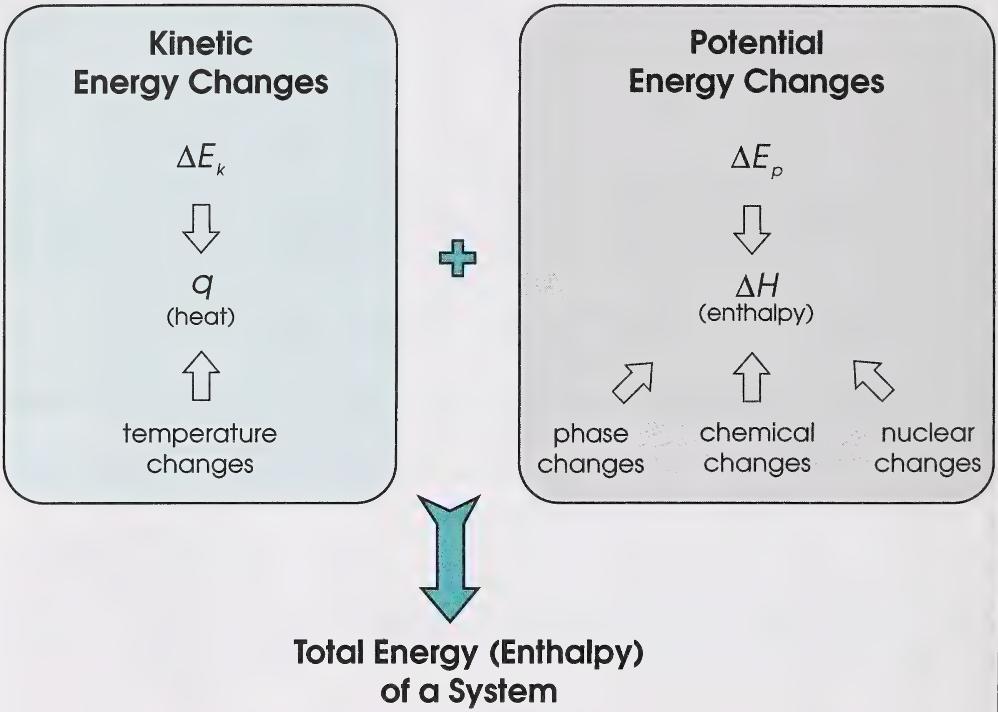


FIGURE 1.4: Energy Involved in Enthalpy Changes

13. If you were to draw a bar graph where phase changes were 1 cm high and chemical changes were 10 cm high, how high would the bar have to be for the nuclear change?

Check your answers by turning to the Appendix, Section 1: Activity 3.

The table (Table 10.2) on page 292 of your textbook provides some very important information. The following graphic summarizes some of the information given.



In Activity 1 you discovered that heat transferred as a result of a temperature change can be calculated using the equation $q = mc\Delta t$. How will you calculate enthalpy changes, ΔH, as previewed in this activity? The answer to this question is in the next activity.

You will find that as you work through this module and Module 2, many situations will arise where it will be important for you to distinguish between kinetic and potential energy changes. A little extra work on your part now to understand the differences will help you a lot down the road.

ACTIVITY

4 The Energy of Phases

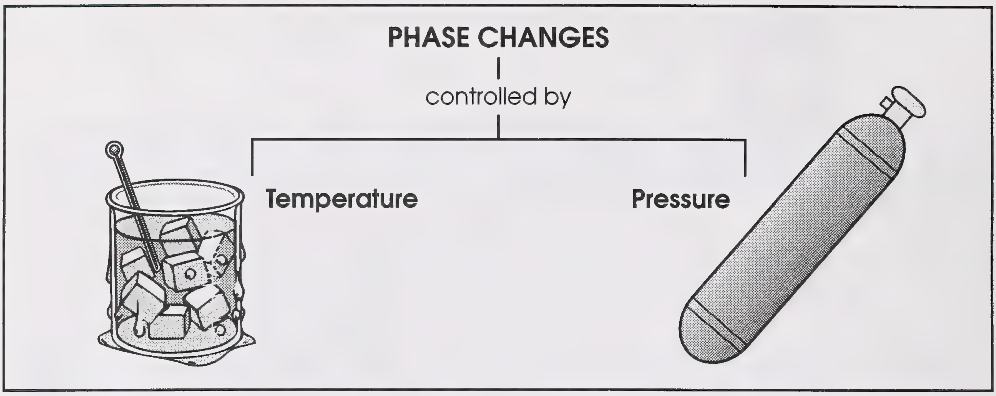
One morning in late fall you wake up and look out your window; you see the trees are covered in snow. What phase change has resulted in a snowfall? The moisture (a vapour) held in the atmosphere changed to snow (a solid).

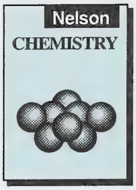
In your experience so far, you already know there are three states that any matter normally exists in – solid, liquid, and gas. These states have unique, as well as common characteristics. You have already studied these characteristics in previous science courses.

1. a. What two factors determine the state in which a substance exists?

   b. What happens when the factors are changed in a particular way?

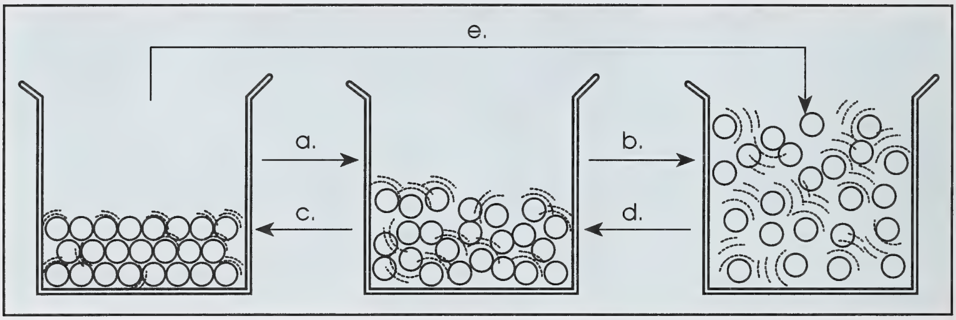
Check your answers by turning to the Appendix, Section 1: Activity 4.





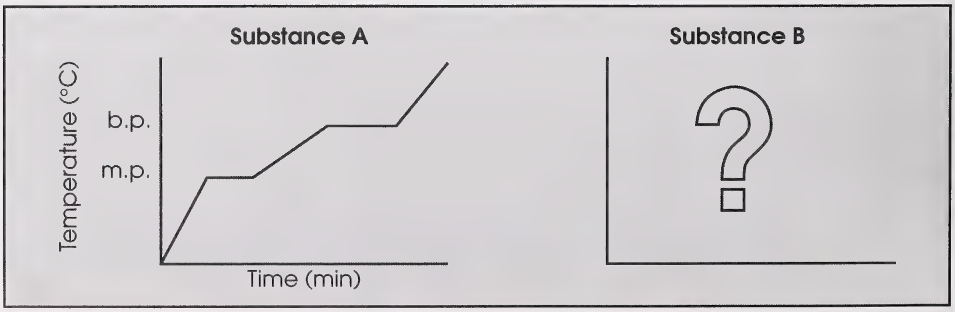
Read Section 10.2: Phase Changes of a System on pages 292 and 293 of your textbook, paying special attention to the diagram at the top of page 293. Check your understanding of phase changes by answering the questions which follow.

2. Using the following diagram, indicate what type of phase change each arrow represents and if the change is endothermic or exothermic.



3. How does the amount of energy absorbed when one mole of water melts compare to the amount of energy released when one mole of water freezes?

4. How would the heating curve of one pure substance compare to the heating of another pure substance?



5. a. The molar enthalpy of fusion (melting) of sodium is 2.6 kJ/mol. What does this statement mean?

   b. What is the symbol that represents molar enthalpy?

6. Refer to Table 10.3 on page 293 of your textbook and note the two enthalpy values given for water. During these changes will the surroundings gain or lose heat?

Check your answers by turning to the Appendix, Section 1: Activity 4.

In Activity 2, you learned that heat energy changes involving changes in temperature could be calculated as follows:

$$q = m \quad c \quad \Delta t$$

q	m	c	Δt
heat energy	mass	specific heat capacity	temperature change
(J)	(g)	$\left(\frac{\mathrm{J}}{\mathrm{g} \bullet {}^{\circ}\mathrm{C}}\right)$	(°C)

How can you solve changes in enthalpy, ΔH, when there are no changes in temperature? How does ΔH arrive at the same units, joules or kilojoules, as q? To answer these questions, read and study the paragraph and sample problem on page 295 of your textbook.

7. Fill in a table which describes the variables of the equation $\Delta H = nH$.

Variable	Description	Units
ΔH		

Please note the reference to other resources that accompanies the Appendix answer to this question.

8. Do questions 15 to 20 on pages 295 and 296 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 4.

If you looked around, could you find examples where a knowledge of phase changes and their energies is put to practical use?

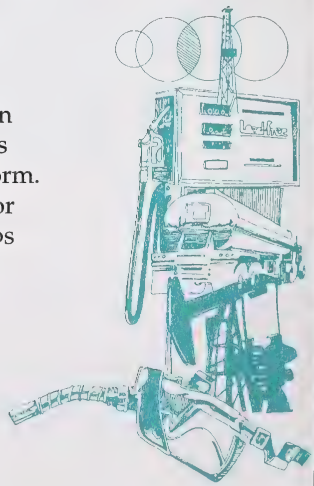
Many ski hills are able to open early and maintain a good snow base by using snowmaking equipment. A snowmaking machine contains a mixture of compressed air and water vapour. Because of the large difference between the atmospheric pressure and the tank, the expelled mixture expands rapidly and with the quick cooling of the gas, the water vapour changes to snow.

1

AGRICULTURE CANADA

The photograph on the left illustrates a situation that sometimes happens to fruit farmers. Farmers often spray water into the air and on their fruit trees to prevent frost damage. Do you know why? The water freezes, releasing heat into its surroundings. This results in raising the temperature of the air. The ice formed acts somewhat as an insulation for the plants from the cold air to reduce further damage to the crop from low temperatures.

Another important application of phase change principles can be found in the petroleum industry. The crude oil that comes straight out of the ground can rarely be used in its existing form. It is a mixture of long- and short-chain organic molecules. For maximum use the oil has to be separated into different groups of compounds. This is one part of the refining process called **fractional distillation**.



fractional distillation – a physical process during which molecules of different sizes are separated as a result of their different boiling points

[1] *The Edmonton Journal* for the photo by Ed Kaiser, November 11, 1993. Reprinted by permission of *The Edmonton Journal*.

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Read pages 241 to 243 in your textbook to learn more about refining; then answer the following questions.

9. Is the separation that occurs in a fractional distillation column a result of physical or chemical processes?

10. Which property of compounds is used to separate the fractions in a fractionating column?

11. Which types of fractions are collected lower in the column and which are collected higher? Explain why.

fractions – different groups of compounds collected in different trays of the fractionating column

Check your answers by turning to the Appendix, Section 1: Activity 4.

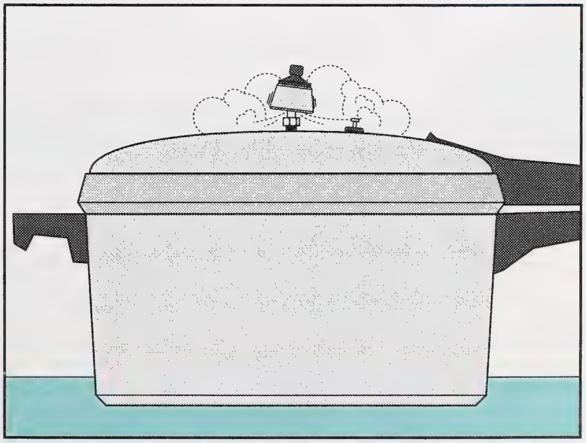
In this activity you have learned how to calculate molar enthalpy changes for phase changes and you have looked at some industrial and environmental applications of the energy principles explained. From what you have studied, you may think that energy changes occur in discrete packages. In the next activity you will learn, though, that the total energy change that a system undergoes is often a combination of several types of energy changes.

ACTIVITY

5 The Total Energy Package

1. Potatoes take less time to cook in a pressure cooker. Explain why.

What types of energy changes occur in the pressure cooker as it cooks food? Is the energy change kinetic (temperature), potential (enthalpy), or a combination of the two? To answer these questions, you have to understand the processes that occur inside the cooker.



As shown in Figure 1.5, heat is transferred to the system in two steps. The step from point A to point B represents heat being absorbed to change the temperature of the water. When the water reaches the pressure cooker boiling point, the section from point B to point C shows that the water absorbs heat energy and uses it as potential energy to boil the water. Therefore the total energy gained by the system (ΔE_{total}) is the sum of the heat transferred to it for raising its temperature (q) and the heat absorbed for boiling (ΔH_{vap}).

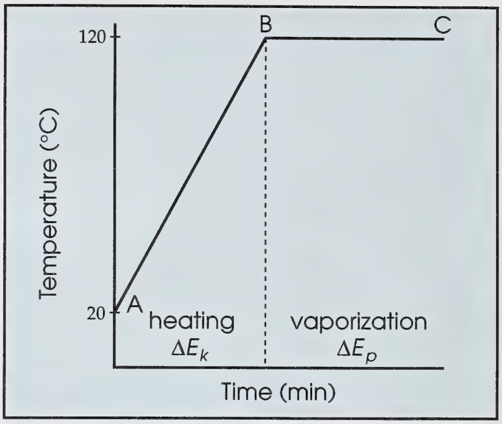
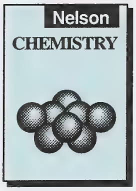


FIGURE 1.5: Heating Curve for a Pressure Cooker

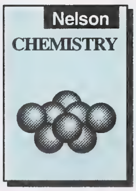
$$\Delta E_{total} = q + \Delta H_{vap}$$



How could you calculate the total energy change in the pressure cooker water? Read pages 296 and 297 of your textbook and study the examples given to see how these types of calculations are performed. Pay special attention to the margin notes on page 297 dealing with using your calculator.

When doing calculations

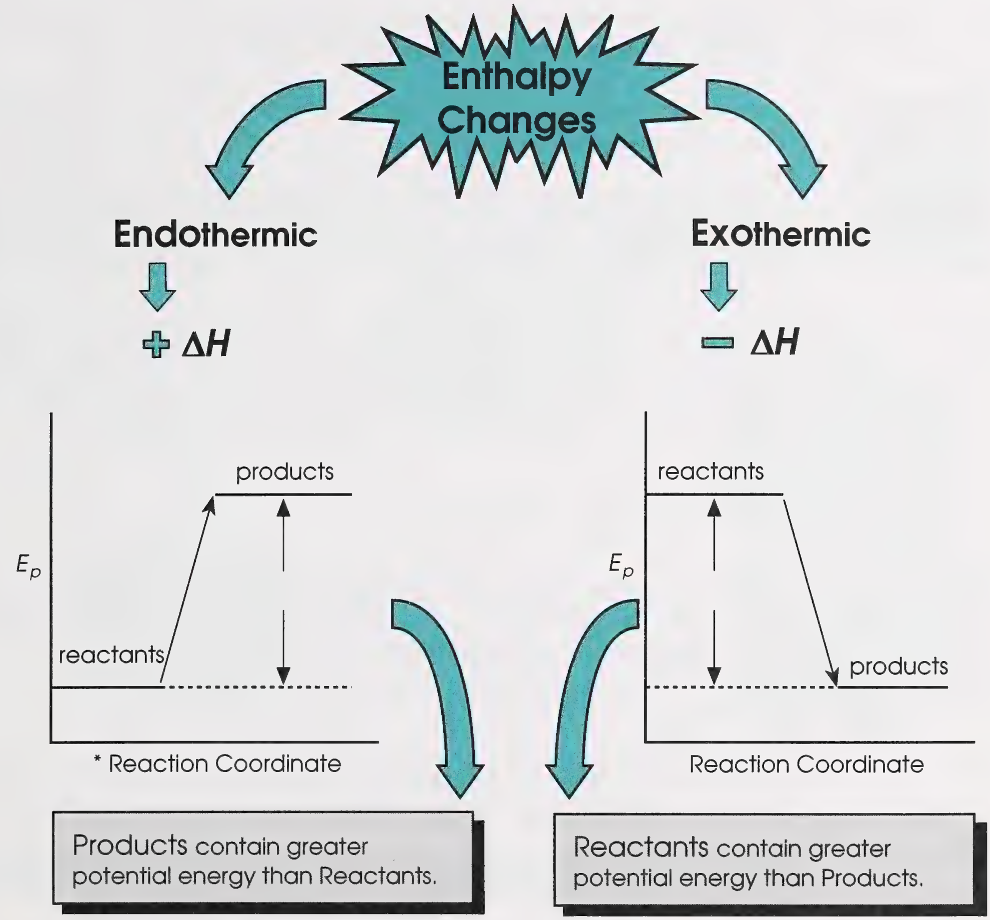
- Pay careful attention to your units.
- Keep all of your digits stored for intermediate step answers. Only round off the final answer. (If intermediate answers are shown as rounded in this course, it is only for illustration.)



2. Do textbook questions 21 and 22 on pages 297 and 299 of *Nelson Chemistry*.

Check your answers by turning to the Appendix, Section 1: Activity 5.

There are several ways of expressing enthalpy changes when indicating a process has been endothermic or exothermic. For more information on this important aspect of energy changes, read pages 299 and 300 in your textbook. Note the margin information.



* **Note:** The reaction coordinate is simply a time frame axis that shows the energy change proceeding from left to right in the diagram. It can also be called reaction progress.

3. Complete the following sentences.

   a. A value for ΔH which is less than zero indicates an __________ energy change.

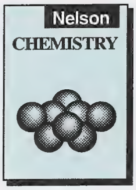
   b. The sign convention method represents an energy change from the perspective of the __________.

   c. An enthalpy change during transition from one state to another is described as an increase or decrease in the __________ of the system.

   d. A decrease in potential energy occurs in an __________ change.

   e. An increase in potential energy occurs in an __________ change.

4. Draw a potential energy diagram for the fusion of 2 mol of NaCl. The molar enthalpy of fusion for this compound is 28 kJ/mol.



5. Answer textbook questions 23 to 26 on pages 300 and 301 of *Nelson Chemistry*.
Note: Textbook question 23. a. should read $H_2O_{(l)}$, not $H_2O_{(g)}$.

Check your answers by turning to the Appendix, Section 1: Activity 5.

You have begun to discover how you can trace the movements of energy through its changes. You have seen how energy changes can be represented by sign convention and potential energy diagrams. Your knowledge forms the basis for the experimentation and energy change measurements you will perform in the next section.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

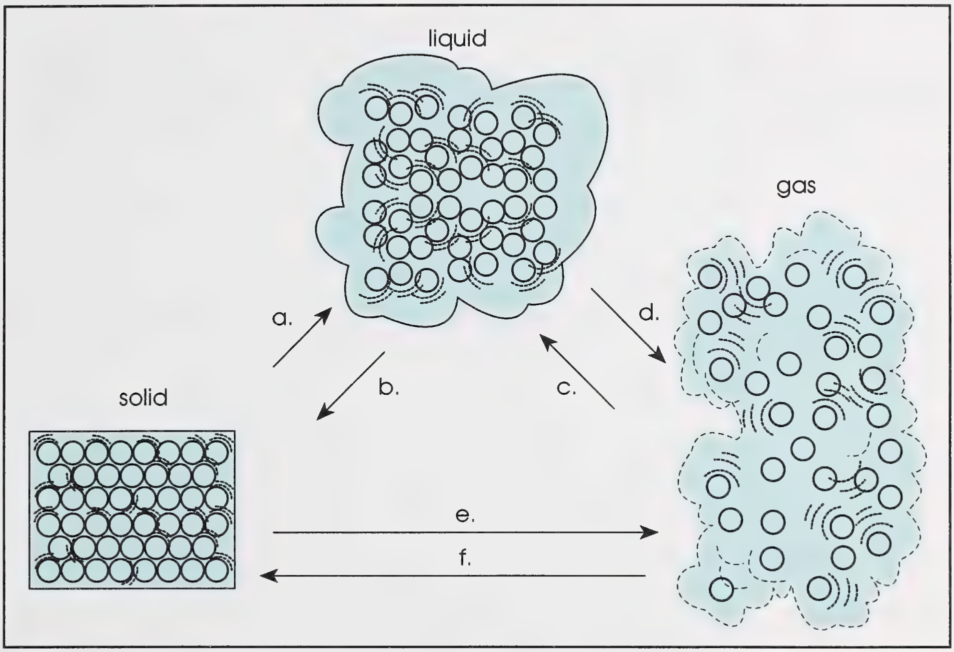
Extra Help

1. In this section, you have seen energy classified according to its sources and its forms. Complete the following table by listing four examples in each column.

Energy Sources	Energy Forms

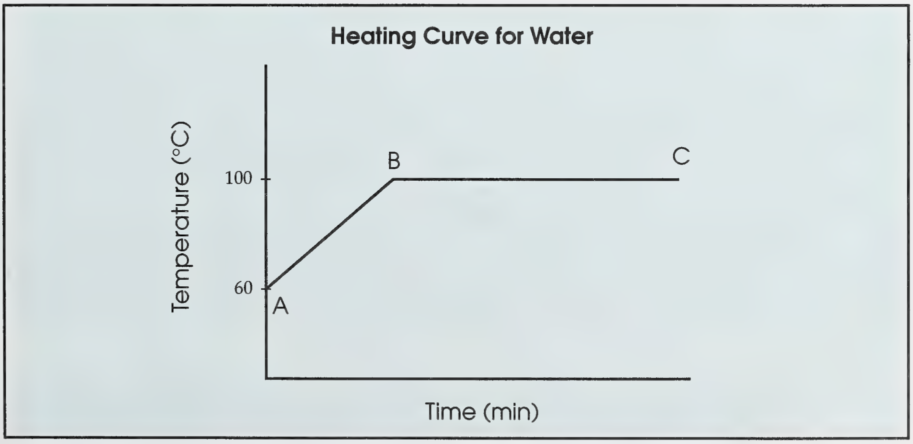
2. Which substance in the following diagram, assuming each has the same mass, will have the greatest increase in temperature when given 10.0 J of heat? The specific heat capacity (in $J/g \bullet °C$) is given for each substance. Explain your answer.

3. Identify the phase changes as labelled in the following diagram. For each phase change, identify whether it is exothermic or endothermic, and what sign (+ or –) its ΔH value would have.



4. The following graph shows a particular heating curve for water.

   a. For each section of the graph, write the mathematical equation used to find the enthalpy change.



   b. How would the total energy change of the system be calculated?

5. How much heat will a 26.8 g ice cube absorb as it changes temperature from –32.4°C to –16.8°C?

6. Use the potential energy diagrams in Figure 1.6 to answer this question.

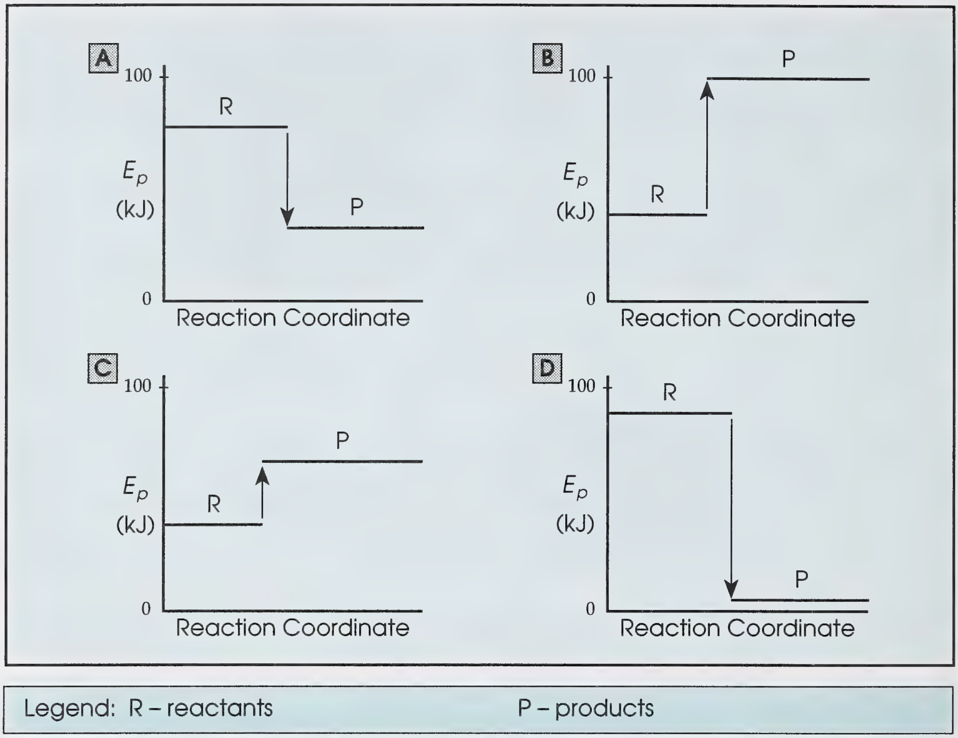


FIGURE 1.6: Potential Energy Diagrams

a. Which of the potential energy diagrams show endothermic changes? Exothermic changes?

b. Which of the potential energy diagrams show energy changes with $-\Delta H$ values?

c. Which of the potential energy diagrams show heat being absorbed?

d. Which of the potential energy diagrams shows the greatest ΔH? Smallest?

e. State a generalization for both endothermic and exothermic energy changes regarding the relative amounts of stored energy in the initial state (reactants) versus the final state (products).

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Do **one** of the following.

1. Research why Glauber's salt is used to store heat in solar homes.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

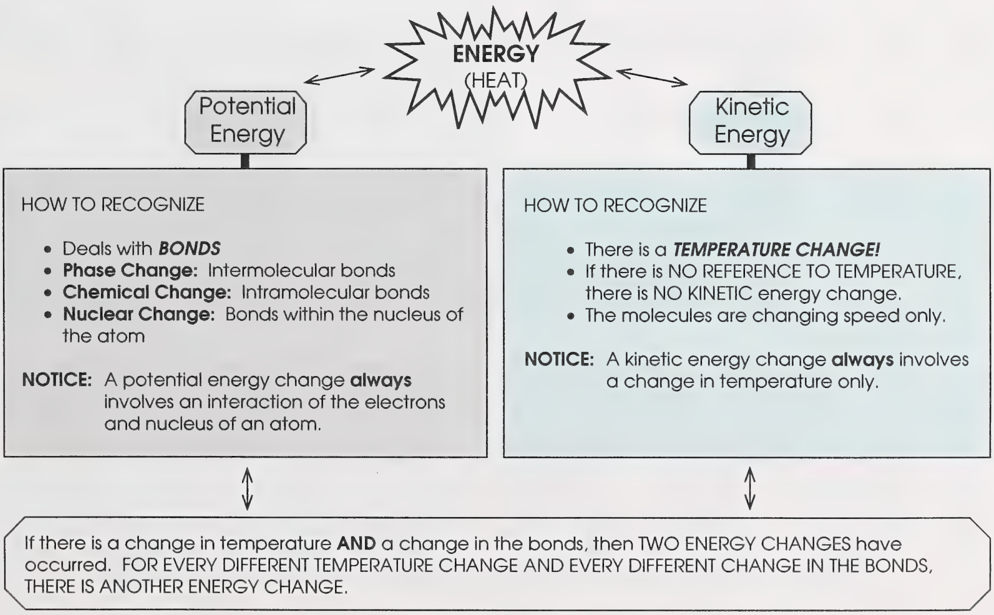
2. Design and perform an experiment to measure the specific heat capacity of water. Your design should include the materials you will need, a procedure to complete the investigation, observations you will need to record, and a complete analysis.

3. Explain why a pizza tray hot out of the oven will burn your skin but the hot oven air usually will not.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

In this section you have learned that thermochemistry is a study of enthalpy changes and heat transfer which take place during nuclear, chemical, and phase changes. In the next section you will look at some methods for measuring energy changes. The following organizer may be useful for you to remember the major concepts taught in this section.



35

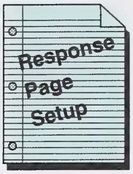
Section 1 Assignment: The Basics of Energy

Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

Chemistry 30 – Module 1 Section 1 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.



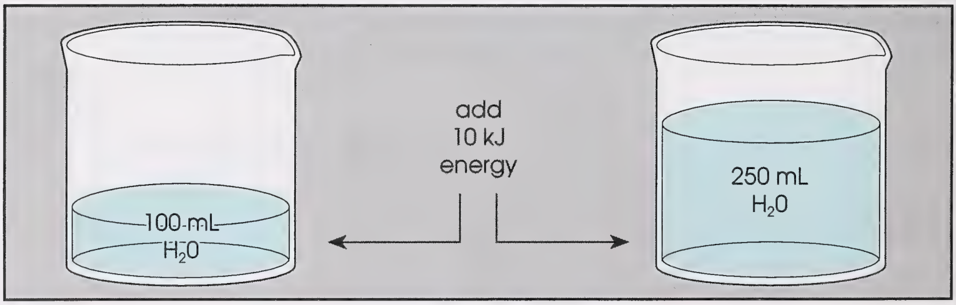
1. A 100.0 g sample of ice at –15°C is heated until it is converted to water vapour at 120.0°C.

   a. Sketch a heating curve for the sample of ice. Be sure to label your diagram. **(3 marks)**

   b. Calculate the total energy change. Show your work clearly. Lay out each step showing the variables involved. **(6 marks)**

2. If 700 mL of water at 25.0°C absorbs 20.0 kJ of heat, what is the final temperature of water? **(4 marks)**

3. Explain the difference between heat and temperature. The following two beakers can be used as an example to illustrate your point. Calculate the temperature change in each system to support your answer. **(6 marks)**



4. Calculate the enthalpy change for the vaporization of 2.00 g of sodium metal given that the molar heat of vaporization for this metal is 101 kJ/mol. **(3 marks)**

5. Describe the type of energy changes occurring in each of the following

   a. muffins baking in an oven **(1 mark)**

   b. hearing someone talking to you on a telephone **(1 mark)**

   c. a person diving into a swimming pool **(1 mark)**

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

6. To study how the temperature of a pure substance changes with time during melting and solidification phase changes, a student performed an experiment using paradichlorobenzene. The student recorded the following observations.

Time (min)	COOLING DATA	WARMING DATA	Time (min)	COOLING DATA	WARMING DATA
	Temperature (°C)			Temperature (°C)	
0.0	62.0	25.0	6.5	53.0	53.0
0.5	59.0	29.0	7.0	53.0	56.0
1.0	58.0	30.0	7.5	53.0	57.0
1.5	56.0	34.0	8.0	52.0	57.0
2.0	55.0	41.0	8.5	52.0	58.0
2.5	54.0	49.0	9.0	52.0	58.0
3.0	53.0	53.0	9.5	52.0	60.0
3.5	53.0	53.0	10.0	52.0	64.0
4.0	53.0	53.0	10.5	49.0	65.0
4.5	53.0	53.0	11.0	46.0	66.0
5.0	53.0	53.0	11.5	40.0	67.0
5.5	53.0	53.0	12.0	37.0	67.0
6.0	53.0	53.0			

a. Plot the data for the cooling and the heating of this compound on the same graph paper. Use a different colour to identify each curve or use *x*'s for the data points on one curve and ⊙'s on the other curve. Use correct graphing techniques. **(4 marks)**

b. Identify the manipulated (independent) variable and the responding (dependent) variable. **(2 marks)**

c. What is the melting point and the freezing point of this compound? **(2 marks)**

d. What effect will increasing the amount of paradichlorobenzene have on the shape of these curves? **(1 mark)**

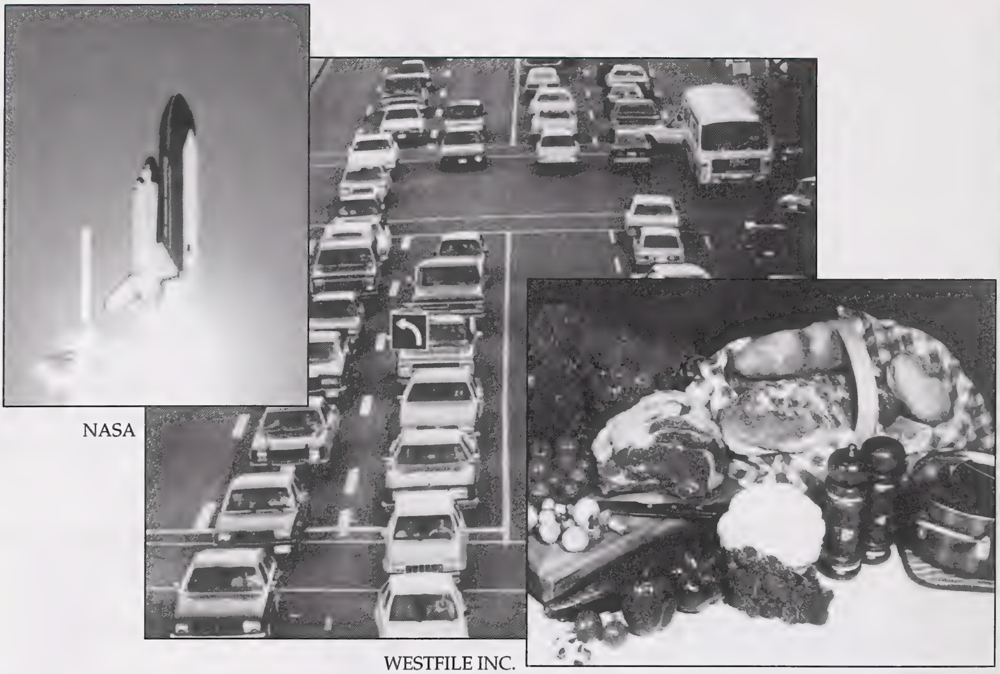
e. Why does the temperature not change during the time interval represented by the plateaus in the graph? **(1 mark)**

Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Leave a space for the teacher assessment.

Self:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

SECTION 2

Calorimetry – Measuring the Invisible



NASA

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What do foods such as sugar and fuels such as gasoline or hydrogen have in common? Do they fill a similar need? Both foods and fuels are sources of energy. The potential energy stored in food provides energy for life on Earth to function. The potential energy in fuels provides energy for an industrialized society to function.

It is important for you to know how much energy is produced by foods and fuels so that you can use them efficiently. To maintain a healthy body, you need to have a balanced food intake. If you are designing machinery, you must make the best use of the fuel.

How can you measure the energy available from these sources? In this section you will learn about heat energy transfer and apply your knowledge to methods of energy measurement. You will then use this principle to measure and calculate heat changes that occur during physical and chemical changes. As well, you will compare the amounts of energy obtained from foods and fuels.

ACTIVITY

1 The Process of Calorimetry

You have just returned from an exciting winter skate. You think to yourself, Hot chocolate would sure taste good right now! You pour yourself a cupful from a thermos and, without thinking, take a big gulp. Ouch, that's hot!

1. Why did the hot chocolate burn your mouth?

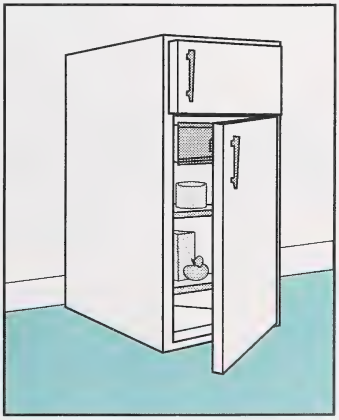
You often learn about heat transfer the hard way, but everyone has experienced it at one time or another. Heat energy transfer is crucial in the measurement of energy changes in systems.

isolated system – a system in which neither energy nor matter can move in or out of the system

calorimeter – a device used for measuring energy changes

To study and measure energy changes, an **isolated system** is required. The thermos in the photograph is designed to be as close as possible to an isolated system. Neither heat energy nor matter can flow out of or into the thermos, as long as the thermos is closed (note that this is the ideal – in reality, a thermos does lose heat slowly). An isolated system is essential for measuring the energy changes which occur during a phase or a chemical change. Scientists have developed an instrument called a **calorimeter** which is an isolated system.

From Section 1, you already know that as matter changes, energy changes occur as well. You have also discovered that heat flows from areas of high temperature to areas of low temperature. In an isolated system this principle is applied to study enthalpy changes.

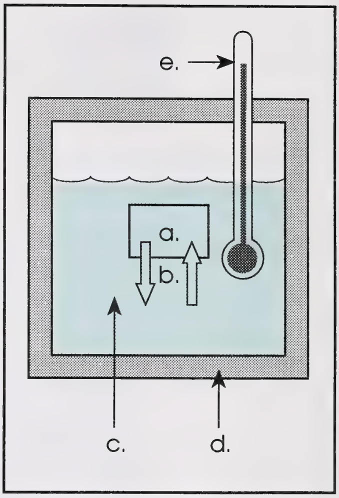


A calorimeter works very much like a refrigerator. Warm food in a refrigerator loses heat to the cold surrounding air until both the food and the air come to the same temperature. Similarly, in a calorimeter the system undergoing the energy change comes to an equilibrium (reaches the same temperature) with the surrounding water in the calorimeter.

Nelson CHEMISTRY

To learn more about the calorimeter and the process of calorimetry, read the section entitled Calorimetry of Physical and Chemical Systems on pages 301 and 302 of your textbook. Also read the information given in the margins of the two pages.

2. Label the diagram of the calorimeter shown on the right by identifying each of the indicated parts.



3. Why is water generally used in calorimeters?

4. What is the general principle that allows you to make measurements in a calorimeter?

5. State the law of conservation of energy as it applies to calorimetry. Who helped establish this law?

6. How can you tell whether the system in the calorimeter is undergoing

   a. an endothermic change?

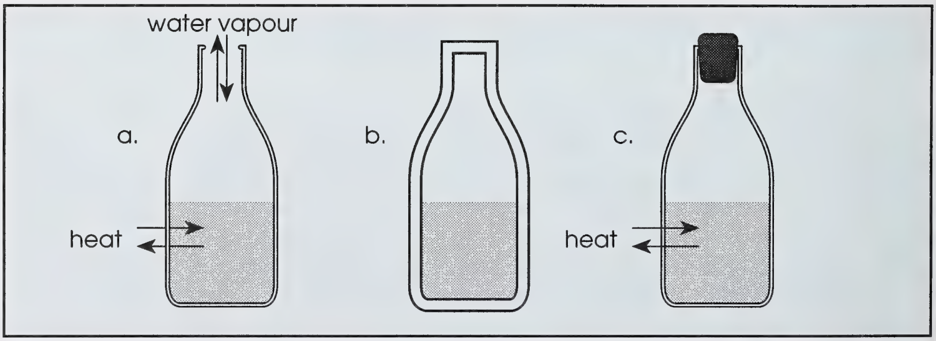
   b. an exothermic change?

7. Explain why a Dewar flask is an isolated system.

8. A student measured the energy change of a system in a calorimeter and determined the value of ΔH to be negative. Using the law of conservation of energy explain how the heat flow occurred in this change.

9. The enthalpy change for dissolving solid LiCl is calculated by using the relationship $\Delta H_s = q$. What do the symbols on each side of the equation represent?

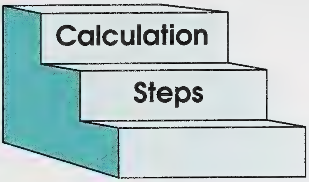
10. In the following diagram indicate which flask represents a closed system, an isolated system, and an open system.



Check your answers by turning to the Appendix, Section 2: Activity 1.

Do you think that the calorimetry calculations you are about to do are new to you? You will find that you have already performed the same type of calculations but you are considering them in a slightly different way.

The following steps will help you when solving most calorimetry problems.



1. Identify the systems undergoing an energy change.
2. Set up the equation for each part of the system.
   $$\Delta H = q$$
3. Rearrange the equation to solve for the unknown.
4. Insert numerical values to solve the problem.

11. Study the example given on page 302 of your textbook to see how energy change calculations are performed for the dissolving of LiCl.

    a. What is losing heat and what is gaining heat?

    b. How is H_s calculated?

    c. What is the difference between ΔH_s and q?

12. Do textbook questions 27 to 31 on pages 303 and 304 of *Nelson Chemistry*.

Check your answers by turning to the Appendix, Section 2: Activity 1.

You will find that there are many variations of calorimetry problems that you will encounter in your studies. The following questions illustrate two such variations.

13. A mass of 65.8 g of solid zinc at 410.0°C is added to 500.0 g of calorimeter water at 15.0°C. The final temperature reached by the mixture is 19.8°C. Determine the specific heat capacity of solid zinc.

14. In the process of melting and warming, a certain mass of ice absorbs 2.52 kJ of heat energy from 100.0 mL of water in a calorimeter. If the calorimeter water had an initial temperature of 25.4°C, what was the final temperature of the entire system?

Check your answers by turning to the Appendix, Section 2: Activity 1.

Calorimetry is a very useful tool and can be quite precise in measuring of energy changes. Can you apply the knowledge you have gained to a practical lab situation? You will have such an opportunity in the next activity.

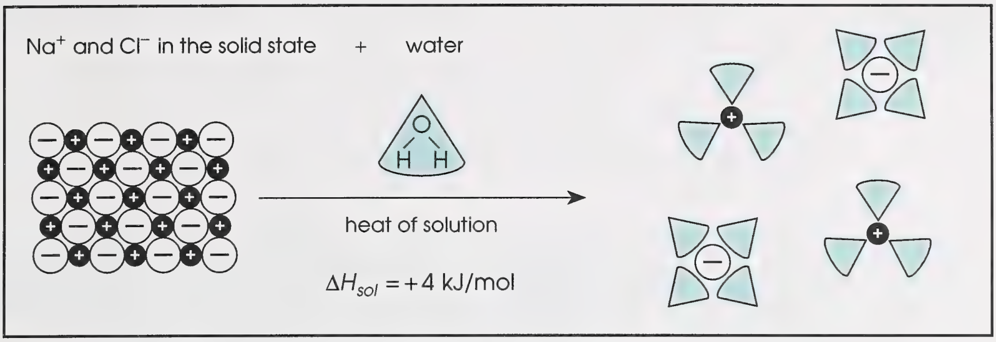
ACTIVITY

2 Using Calorimetry

Nelson CHEMISTRY

In the previous activity, you learned about the basic principles of calorimetry. But what does a calorimeter look like? Does it resemble a thermos? As shown in the drawing in the margin on page 303 of your textbook, the calorimeter used in a school laboratory is often a very simple device made from two polystyrene cups and a thermometer. This type of a calorimeter is used for reactions involving aqueous solutions. When using such a calorimeter it is assumed that all the heat is gained or lost by the water with no heat gained or lost by the cup or the surroundings. Physical or chemical changes involving small heat changes (those causing less than a 25°C change in the calorimeter) usually give fairly accurate results.

One such change is in the dissolving of table salt $\left(NaCl_{(s)}\right)$ in water. The following diagram illustrates how a grain of salt dissolves. You studied this in Chemistry 20.



Use the preceding diagram to answer the following questions.

1. Is the energy change involved endothermic or exothermic?
2. Write a chemical equation that represents the dissolving of $NaCl_{(s)}$. (You might remember this is called a dissociation equation.)

Check your answers by turning to the Appendix, Section 2: Activity 2.

The energy change involved when dissolving occurs is called the heat of solution. The following investigation involves using a calorimeter to determine the heat of solution.

Investigation 10.2: Molar Enthalpy of Solution

Nelson CHEMISTRY

Carefully follow the directions given for Investigation 10.2 on page 303 of *Nelson Chemistry*. Pay special attention to the required components, safety aspects, and applied science skills.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

Guidelines

- Note the design of the calorimeter in Figure 10.23 on page 303 of your textbook. The lid can be made out of cardboard if you don't have polystyrene.
- The chemical used in this experiment is ammonium chloride $\left(NH_4Cl_{(s)}\right)$.
- You will need approximately 2 mL (one-half teaspoon) of the solid ammonium chloride per trial if you are doing this at home.

Nelson CHEMISTRY

- Your calculations, materials, and evidence as outlined in the following questions should be completed on separate paper. If you are uncertain about any of the steps in an investigation, review pages 18 and 19 in your textbook.

3. Calculate the mass of ammonium chloride required to make 100 mL of a 1.00 mol/L solution.

4. Make a list of materials needed to complete this investigation.

5. Prepare an evidence table and record your observations as you perform the investigation.

Check your answers by turning to the Appendix, Section 2: Activity 2.

To complete the analysis answer the following questions.

6. Calculate the temperature change in each trial and the average temperature change.

7. Calculate molar enthalpy of solution for ammonium chloride.

8. Is the energy change you observed endothermic or exothermic? Operationally, how can you tell?

9. Write a balanced equation for the dissolving of ammonium chloride.

10. Draw a potential energy diagram to illustrate the energy change that occurred.

Nelson CHEMISTRY

11. The predicted or accepted value for the heat of solution of ammonium chloride is 14.8 kJ/mol. What is the percent difference in your result? (If you have forgotten how to calculate percent difference, refer to page 546 in your textbook.)

12. How would the value of ΔH_s change if you used two times the amount (moles) of the solute? How would the value of H_s change?

Check your answers by turning to the Appendix, Section 2: Activity 2.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

It sometimes takes a lot of practice in working with the calorimetry principles you have learned before you become really comfortable in doing the energy calculations that go with them. For more practice in applying calorimetry principles, do Lab Exercises 10 A and 10 B on page 304 of your textbook. Read the information carefully and then answer the problem for each exercise.

13. Read Lab Exercise 10 A: Designing a Calorimetry Lab. Calculate the mass of ammonium nitrate needed.

Science Skills

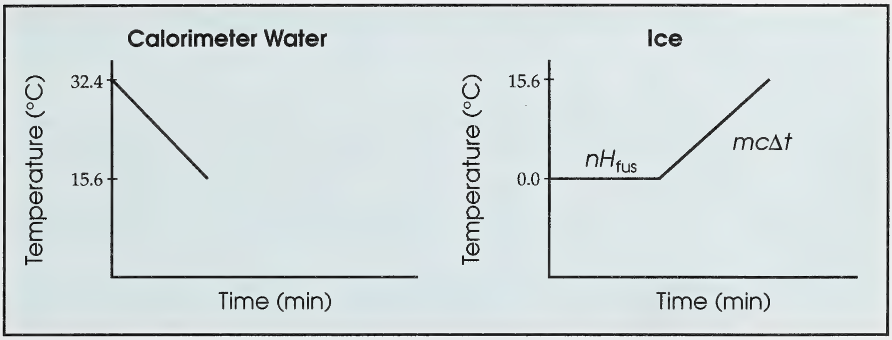
- ❐ A. Initiating
- ❐ B. Collecting
- ❐ C. Organizing
- ☑ D. Analysing
- ❐ E. Synthesizing
- ❐ F. Evaluating

14. Answer the question posed by the problem in Lab Exercise 10 B: Molar Enthalpy of a Phase Change. You may wish to solve the problem in steps as follows, or you can solve the problem in one step if you are comfortable with the mathematics.

    a. Identify the process gaining heat and the one losing heat.

    b. Calculate the heat lost by the original water in the calorimeter.

    c. The ice will first undergo a phase change (melt) and then the ice water will increase in temperature. Calculate the total heat gained by the ice melting, then warming (as far as you can).



    d. Equate the heat lost by the calorimeter water to the heat gained by the ice and solve for the molar enthalpy of fusion (melting) of ice.

Check your answers by turning to the Appendix, Section 2: Activity 2.

The following questions will give you more practice in solving calorimetry problems.

15. A sample of water is heated from 20.0°C to 25.0°C by a reaction which gives off 8.05 kJ of heat. What is the mass of water in the calorimeter?

16. A mass of 8.50 g of sodium nitrate is dissolved in 100.0 mL of water in a calorimeter. If the in temperature decrease of the water is 5.2°C, calculate the molar heat of solution of sodium nitrate.

Nelson CHEMISTRY

17. A 70.0 g piece of copper metal at 95.2°C is dropped into 101 g of calorimeter water at 22.5°C. Calculate the final temperature of the whole system. (**Reminder:** The specific heat capacities of pure substances can be found on the back inside cover of your textbook.)

18. A student dissolved enough potassium nitrate in 100.0 mL of water in a calorimeter to make a 1.0 mol/L solution. If the student calculated the molar enthalpy of solution to be +34.8 kJ/mol, what change in temperature occurred?

19. A mass of 20.0 g of steam at 100.0°C is bubbled into some calorimeter water initially at a temperature of 20.2°C. When the steam condenses to water and cools, the final temperature of the system reaches 39.9°C. Calculate the original mass of the calorimeter water.

20. A student completely burned a small candle and found that burning the candle warmed 50 g of water from 20°C to 26°C. If the student were to repeat the experiment using an identical candle and, this time, 150 g of water at 20°C, what would be the expected final temperature of the water?

Check your answers by turning to the Appendix, Section 2: Activity 2.

As you have discovered, calorimetry techniques can be very useful in determining the energy changes of various processes. A simple change in calorimeter water temperature can often allow you to solve more complex energy changes in systems. Will this process allow you to solve for energy changes in chemical systems?

ACTIVITY

3 Chemical Changes and Calorimetry

Nelson CHEMISTRY

Enthalpy changes during chemical reactions can be quite large, which could lead to a serious burn. Firefighters rely quite heavily on the fact that their clothing will protect them when fighting fires. The photograph in the margin on page 309 of your textbook shows you the importance of determining the energy changes associated with some types of chemical changes.

[1] *The Edmonton Journal* for the photograph of October 22, 1993. Reprinted with permission of *The Edmonton Journal.*

1. If you accidentally spilled some acid in the laboratory, which of the following would you choose to get the acid off your hands?

   - cold water
   - sodium hydroxide
   - hot water

Check your answers by turning to the Appendix, Section 2: Activity 3.

Sodium hydroxide is not a good choice because when it is mixed with an acid a strong exothermic reaction occurs which will further burn your skin.

How could researchers measure these enthalpy changes? Would calorimetry methods work?

In the next investigation, you will see that many types of chemical changes can be determined using the same calorimetry techniques you have already used.

Investigation 10.3: Molar Enthalpy of Reaction

Carefully read the directions given for Investigation 10.3 on page 305 of *Nelson Chemistry*. Pay special attention to the required components, safety aspects, and applied science skills.

Pre-lab

2. Before you can complete the procedure for this investigation, you will need to calculate the volume of 1.0 mol/L sulphuric acid needed to completely react with 50 mL of 1.0 mol/L sodium hydroxide solution.

   a. Write a balanced equation for the reaction between sulphuric acid and sodium hydroxide.

   b. Calculate the minimum volume of 1.0 mol/L $H_2SO_{4(aq)}$ required to completely react with 50 mL of 1.0 mol/L NaOH.

Check your answers by turning to the Appendix, Section 2: Activity 3.

3. Write a brief experimental design to describe your investigation.

4. Make a list of materials needed to complete the investigation.

5. Write a procedure in step form for this investigation.

Check your answers by turning to the Appendix, Section 2: Activity 3.

PATHWAYS

If you have access to supervised laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.

Part A

Science Skills
- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Caution

6. Prepare an evidence table similar to the one following, carry out your procedure, and record your observations.

Data	Trial 1	Trial 2	Trial 3
volume of 1.0 mol/L $NaOH_{(aq)}$ (mL)			
volume of 1.0 mol/L $H_2SO_{4(aq)}$ (mL)			
initial temperature of $H_2SO_{4(aq)}$ (°C)			
initial temperature of $NaOH_{(aq)}$ (°C)			
final temperature of the mixture (°C)			

Check your answers by turning to the Appendix, Section 2: Activity 3.

To complete the analysis, do the questions after Part B.

End of Part A

Part B

Science Skills
- ☑ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Because of the dangers involved in shipping strong acid and base solutions, you will not actually perform the investigation.

7. Prepare an evidence table and obtain the evidence from the Appendix, question 6, Section 2: Activity 3.

As your analysis, do the following questions.

End of Part B

Analysis

8. a. Calculate the average temperature change.

   b. Calculate the molar enthalpy of neutralization of 1.0 mol/L sodium hydroxide with 1.0 mol/L sulphuric acid.

   Note: If you are somewhat confused about what has happened during the chemical change in this investigation or are confused about what data values to use with the different variables, you can consult the explanation that is included with the answer for this question in the Appendix.

9. Evaluate your result by calculating the percent difference or percent error.

Check your answers by turning to the Appendix, Section 2: Activity 3.

In the preceding investigation, you made two basic assumptions that allowed you to perform your energy calculations.

Assumptions

- **Minimal heat is lost or gained by the calorimeter or surroundings.**
- **The calorimeter solution has a specific heat capacity similar to water.**

To help evaluate these assumptions, answer the following question.

10. Answer textbook question 32 on page 305 of *Nelson Chemistry*.

Check your answers by turning to the Appendix, Section 2: Activity 3.

The neutralization reaction you worked with in the preceding investigation involves relatively small energy changes. Not all chemical reactions are like that.

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Combustion reactions involve large exchanges of energy. An example of a combustion reaction you will investigate is a candle burning. Energy changes of such reactions cannot be measured in a simple calorimeter because the polystyrene will melt before the heat can be transferred to the water. But there are alternate methods which can be used. The following investigation will show you how a simple metal calorimeter can be constructed to determine the molar enthalpy of combustion.

Nelson CHEMISTRY

Investigation 10.4: Designing a Calorimeter for Combustion Reactions

Carefully follow the directions given for Investigation 10.4 on page 306 of *Nelson Chemistry*. Pay special attention to the required components, safety aspects, and applied science skills.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Caution

Guidelines

- You can use the calorimeter you made for Investigation 10.1 in Section 1: Activity 2 (if you saved it) or make a similar one for this investigation.
- Make use of materials from around your home as much as possible.
- Pay special attention to the assumptions listed under the title Experimental Design.
- Try to keep your design simple and avoid using flammable materials.

11. Based on the given problem, predict what design will give the best results.

12. Make a list of the materials you will need. Include a labelled drawing of your calorimeter.

13. Write a procedure in step form. Your procedure should account for varying the position of the candle and the size of the flame.

14. Prepare an evidence table, carry out your procedure, and record your observations.

Complete the analysis by answering the following questions.

15. a. Write the chemical equation for the complete combustion of paraffin wax.

    b. Is the reaction endothermic or exothermic? How can you tell that?

16. Show your calculations for determining the molar heat of combustion of paraffin wax for each trial.

17. Evaluate the design of your calorimeter based on your results.

Check your answers by turning to the Appendix, Section 2: Activity 3.

From the preceding investigation, you have experienced for yourself that it takes a fair amount of time to research the best design and carry out careful data collection. However, when the data supports your prediction and answers the problem, you get a feeling of satisfaction.

The following questions will give you further practice in solving calorimetry problems dealing with chemical changes.

18. A mass of 0.136 g of $Mg_{(s)}$ is burned completely in the bomb (inner container) of a calorimeter containing 300 mL of water. Calculate the molar enthalpy of combustion of magnesium if the temperature change was measured to be 1.13°C.

19. A volume of 50.0 mL of 1.0 mol/L hydrochloric acid is added to 25.0 mL of a 1.0 mol/L $NaOH_{(aq)}$ solution. The following data were collected:

initial temperature of $HCl_{(aq)}$ (°C)	= 24.0
initial temperature of $NaOH_{(aq)}$ (°C)	= 22.0
final temperature of mixture (°C)	= 32.3

Calculate the molar heat (molar enthalpy) of neutralization for $NaOH_{(aq)}$.
(**Hint:** Be careful with the initial temperature you use in your calculation!)

20. What mass of ethane, $C_2H_{6(g)}$, needs to be burned in a calorimeter to heat 800 g of water from 25.0°C to 90.0°C? The molar heat of combustion for ethane is –1428 kJ/mol.

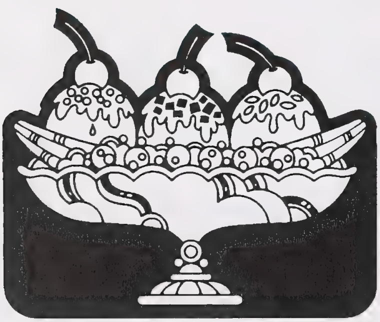
Check your answers by turning to the Appendix, Section 2: Activity 3.

The chemical changes studied in this activity have shown a greater magnitude of energy change than the phase changes studied earlier. It is important to study chemical change energies because they relate directly to the processes that occur in your body as a result of activities such as eating and cellular respiration. The next activity will explore energy changes related to foods and fuels.

cellular respiration – the process by which energy is obtained in organisms from the reaction of compounds such as glucose

ACTIVITY

4 Foods and Fuels



Did you know that eating a banana split gives you about four million joules of energy? A hamburger gives you a million joules.

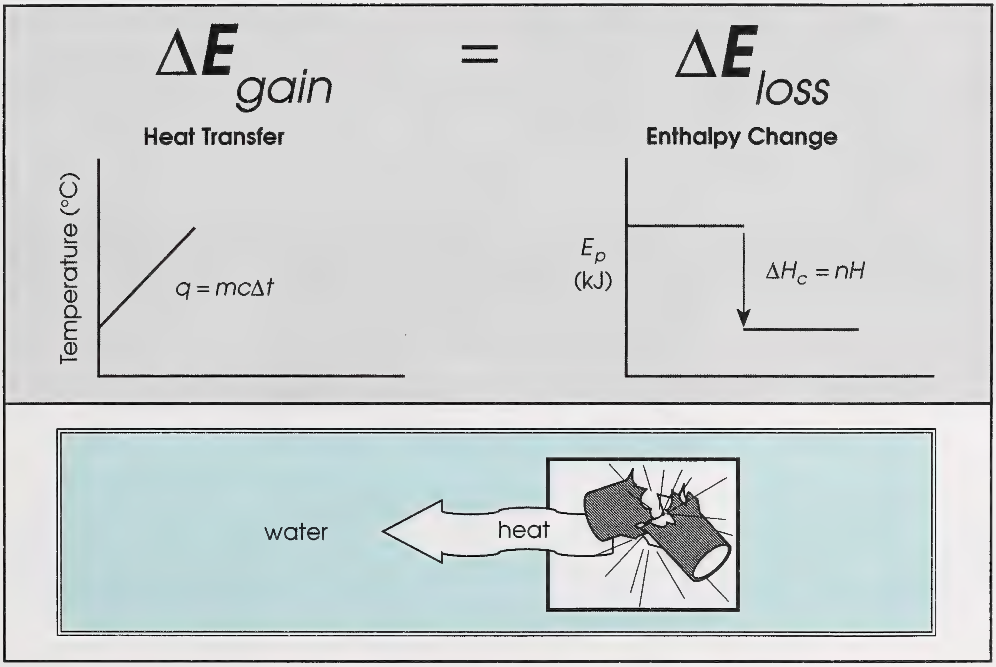
1. How many food calories (1 food calorie = 4.19 kJ) would the banana split and hamburger contain?

Check your answers by turning to the Appendix, Section 2: Activity 4.

bomb calorimeter – thick-walled calorimeter that can withstand high pressure

How can you measure the energy obtained from different foods (fuel for the body) and other types of fuels? Could you use a simple polystyrene calorimeter? To make accurate measurements you need a device which will not release the products of combustion – carbon dioxide and water vapour. It must also be an isolated system. This special type of a calorimeter is called a constant volume **(bomb) calorimeter**.

The diagram in Figure 10.24 on page 307 of your textbook shows a cross section of a bomb calorimeter. The following graphic of an exothermic change illustrates the principles and concepts behind the calorimeter.



Read pages 307 and 308 of *Nelson Chemistry* to learn how to calculate energy changes in a bomb calorimeter. Pay special attention to the example at the bottom of page 307 and on the top of page 308.

2. List four possible substances for which you need a bomb calorimeter to determine the molar heat of combustion.

3. Fill in the following blanks using the given list of words and terms.

- heat capacity
- components
- simple calorimeter
- C
- ΔE_{total}
- total
- bomb calorimeter

a. A __________ has a higher heat exchange with the reaction mixture compared to a __________.

b. In a bomb calorimeter the __________ energy change of the calorimeter is equal to the sum of the energy changes of all the __________.

c. In the equation

calorimeter = water + container + stirrer + thermometer,

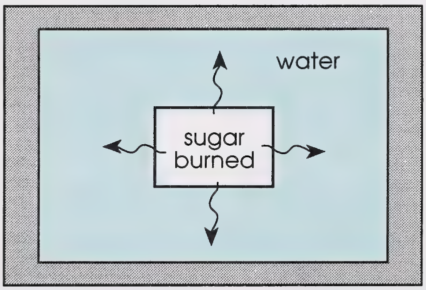
the symbol used to represent the energy change of the calorimeter is __________.

d. The total energy absorbed or released per degree Celsius for the complete calorimeter is called __________.

e. In the equation $\Delta E_{total} = C\Delta t$, the symbol representing heat capacity is __________.

4. A sample of sugar is burned in a bomb calorimeter as shown:

Calorimeter



t_i of water = 20.0°C
t_f of water = 73.0°C

a. Explain the energy changes taking place in terms of potential and kinetic energy.

b. Draw a heating curve to show the energy change for water.

c. Write the mathematical relationship used to determine the enthalpy change.

Nelson CHEMISTRY

5. Answer textbook questions 33 to 35 on page 308 of *Nelson Chemistry*.

Check your answers by turning to the Appendix, Section 2: Activity 4.

Nelson CHEMISTRY

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

In today's increasingly health-conscious society, there is a greater concern about the consumption of fats and sugars in one's diet. Although there may be health problems associated with the excessive consumption of fats and sugars, both substances provide a high source of energy. But which one is higher? To find the answer, work through Lab Exercise 10 D: Energy Content of Foods on page 309 of your textbook.

6. Complete the analysis for Lab Exercise 10 D.

7. Write an evaluation of the investigation report in Lab Exercise 10 D.

WESTFILE INC.

Check your answers by turning to the Appendix, Section 2: Activity 4.

You have seen how fats and sugars can be burned in a calorimeter. Can you imagine what it would be like if fats and sugars burned this way in your body? It would sure justify the phrase "hot under the collar"!

DID YOU KNOW?

The theoretical molar heat of combustion of sucrose is –5630 kJ/mol. No wonder you get a surge of energy when you eat a lot of sugar!

lucose – an rganic molecule sed as an nergy source by ving things

nzymes – hemicals which icrease the eaction rate

Similar reactions to the calorimeter combustion do occur in your body, but they are more complicated and do not involve direct burning with flames, etc. Fats are turned into **glucose**, a sugar, which is then slowly reacted in your cells. In the process, energy is released. This cellular respiration process would be much slower than it already is if it wasn't for **enzymes** participating in the process.

Figure 1.7 shows where this glucose reaction process occurs in your cells.

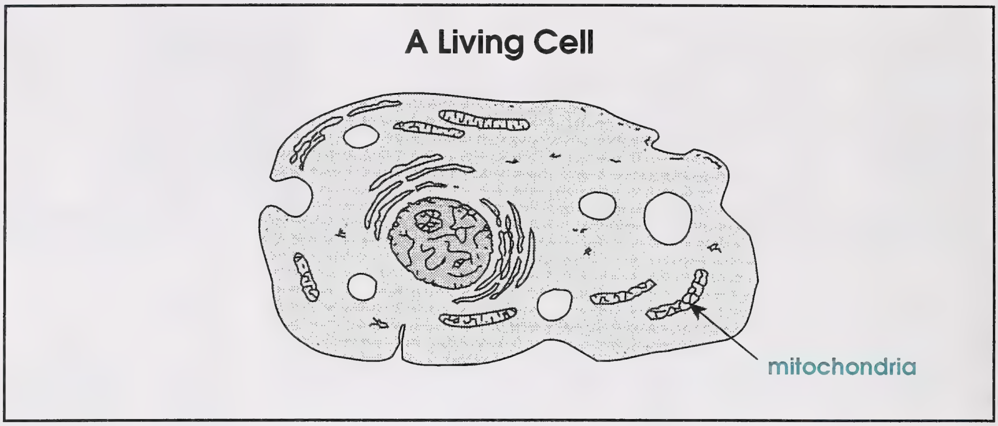


FIGURE 1.7: Site of Glucose Reactions in Body Cells

mitochondria – the structure in a cell where energy is produced

The chemical equation representing the energy change in body cells is as follows:

$$C_6H_{12}O_{6(s)} + 6\,O_{2(g)} \xrightarrow{\text{enzymes}} 6\,CO_{2(g)} + 6\,H_2O_{(l)} + \text{energy}$$

$$\text{(glucose)} + \text{(oxygen)} \longrightarrow \begin{pmatrix}\text{carbon}\\ \text{dioxide}\end{pmatrix} + \text{(water)} + \text{(energy)}$$

ADP – an organic molecule which traps energy

The energy released is trapped by special molecules called ADP. ADP first bonds to a phosphate ion to store chemical energy. This bond (in ATP) has a high potential energy and the process is endothermic.

$$\textbf{ADP} + \textbf{energy} \xrightarrow[\text{endothermic}]{\text{phosphate}} \textbf{ATP}$$

The ATP bond is broken when you do work to release energy – an exothermic process.

$$\textbf{ATP} \xrightarrow{\text{exothermic}} \textbf{ADP} + \textbf{phosphate} + \textbf{energy}$$

DID YOU KNOW?

One teaspoon of table sugar gives about 57 kJ of heat energy. This is equivalent to about 15 calories of food energy.

8. a. Write the balanced chemical equations for the combustion of glucose, a fuel for your body, and the combustion of methane, a fuel for machines.

   b. List two ways that the combustion (metabolism) of glucose in your body is similar to the combustion of methane in machines. List two ways in which these reactions are different.

Check your answers by turning to the Appendix, Section 2: Activity 4.

Knowledge of the energy changes involved in the chemical reactions of both foods and fuels is important to your everyday functioning. In this section you have discovered how energy changes of this nature can be measured. Even though the equipment to measure these chemical energy changes is often more sophisticated than the equipment used to measure phase change energies, the concept remains the same.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

1. Complete the following table by placing a check mark in the appropriate column.

	CALORIMETER	
System Description	**Temperature Increases**	**Temperature Decreases**
ice at 0°C changes to water at 10°C		
sodium hydroxide solution reacts with sulphuric acid		
peanut burns in a bomb calorimeter		
steam at 100°C changes to water at 90.0°C		

2. List two assumptions made when using a simple calorimeter to determine the energy change of the system in the calorimeter.

3. a. A mass of 2.0 g of solid sodium hydroxide is added to 100 mL of water in a calorimeter. A 6.0°C increase in temperature was recorded. Write the mathematical equation, showing all the variables, you would use to find the molar heat of solution for sodium hydroxide.

   b. Calculate the molar heat of solution for question 3. a. Show all your calculations.

4. You are given the following list of steps used in calorimetry investigations. Arrange the steps in the correct sequence.

   a. Add the chemical system being studied to the calorimeter.

   b. Record the final temperature of the calorimeter water.

   c. Record the mass of the water in the calorimeter.

   d. Record the initial temperature of the calorimeter water.

5. Create a chart with the following heading:

Variable	Units

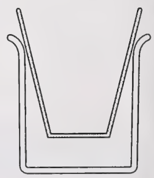
   Fill in the chart for each of the following variables: ΔE_{total}, c, H, ΔH, q, and C.

6. A substance has a molar heat of combustion of –810.4 kJ/mol. When 0.285 mol of the substance is burned in a calorimeter containing 8.60 kg of water, what is the increase in temperature observed?

7. Match the type of change with the relative amount of energy involved as indicated by size of the energy term.

Phase Change	**Energy**
Chemical Change	Energy

8. Reproduce the version of a simple calorimeter shown on the right. Fill in the missing parts as if you were going to perform a calorimetry investigation and label the diagram.



Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

Do any **one** of the following.

1. When someone's body temperature increases for prolonged periods of time, it can be fatal. The human body has some mechanisms to cope with this situation. Research and write about one such mechanism your body uses to dissipate heat energy to the surroundings. You may choose to talk to a health care professional for your research.

2. Society has become obsessed with diets and excess body weight. Do some library research into how energy measurements for various activities are calculated for people. An alternative would be to visit a fitness clinic or a health clinic and discuss this topic with an expert.

3. Design and carry out an investigation to determine the heat of combustion per gram for a peanut. Your report should include a list of materials, procedure, an evidence table, analysis, and evaluation.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

In this section you have seen how different types of calorimeters can be used to measure energy changes. These experimental values can be compared to the theoretical values to evaluate the design of a calorimeter. You also applied the principles of calorimetry to calculate enthalpy changes in chemical reactions. Knowledge of these principles then allowed you to compare various processes as to the energy changes involved.

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Section 2 Assignment: Calorimetry – Measuring the Invisible

Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

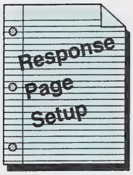
Chemistry 30 – Module 1 Section 2 Assignment Page # Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

1. Your body needs to heat the cold water that you drink to 37.0°C. A slice of cake gives about 1000 kJ of heat when metabolized by your body. How much cold water, at 2.0°C, do you need to drink to make up for (that is, use up the kilojoules gained by) eating a slice of cake? Show your work. **(4 marks)**

2. a. A mass of 45.0 g of molten (liquid) silver at its melting point is poured into 750 mL of calorimeter water at 25.0°C. The final temperature reached by both is 30.0°C. If the specific heat capacity of silver is 0.235 kJ/kg•°C, calculate the molar heat of solidification of silver. Show all your work. **(5 marks)**

   b. Draw a cooling curve representing the energy changes that silver undergoes. **(4 marks)**

   You do not have to use graph paper for your response. However, draw both axes using a ruler, and label your cooling curve properly. Each axis should be between 5 cm and 8 cm in length.

3. In an experiment designed to determine the temperature change of water when heated by three different metals, a 100 g piece of each metal was heated to 300.0°C and then dropped into a polystyrene calorimeter containing 250 mL of water initially at 25.0°C. (Assume no water is lost by vaporization.) The final temperature of the systems were recorded as follows:

aluminum + water system	$t_f = 46.7°C$
copper + water system	$t_f = 34.6°C$
iron + water system	$t_f = ?$

   a. Determine the final temperature of the iron + water system. Show your work. **(4 marks)**

   b. Explain why these three metals cause different changes in the temperature of water. **(1 mark)**

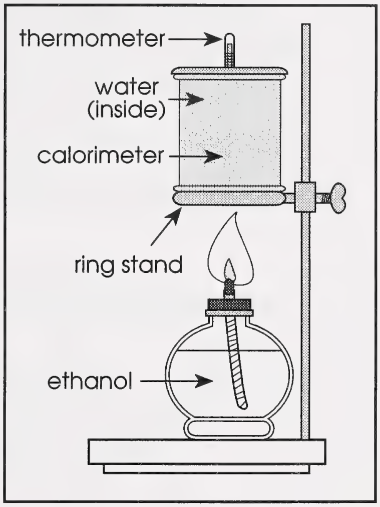
   c. Which of these three metals, when made into a cooking pot, will keep water warm the longest when the pot is removed from the stove? Why? **(2 marks)**

   (Assume that the mass of each pot, the initial temperature of the water, the amount of water, and the rate of heat loss to the surroundings are the same for all three metals.)

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

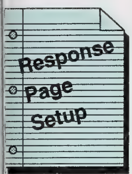
4. A student collected the following data while attempting to determine the molar heat of combustion of ethanol, C_2H_5OH, experimentally. The apparatus used was similar to the one shown on the right. The student performed one trial.



initial mass of ethanol and burner	= 127.67 g
final mass of ethanol and burner	= 124.47 g
mass of calorimeter	= 0.113 kg
mass of calorimeter and water	= 0.363 kg
initial temperature of water	= 20.0°C
final temperature of water	= 90.0°C

a. Determine the student's experimental molar heat of combustion of ethanol from the given data. Show your work. **(4 marks)**

b. If the accepted value for this reaction is – 1235 kJ/mol, calculate the student's percent error, showing your work. Briefly evaluate the investigation. **(2 marks)**



Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Leave a space for the teacher assessment.

Self:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

5. Equal volumes of ethanol, $C_2H_5OH_{(l)}$, and hexane, $C_6H_{14(l)}$, are heated to their boiling points using the same constant heat source. It takes 20 s to vaporize 3.0 g of hexane and 50 s to vaporize 3.0 g of ethanol.

a. Which of the two liquids has stronger intermolecular bonds? Explain your choice. **(2 marks)**

b. If 2.75 kJ are needed to vaporize 3.0 g of ethanol, how much energy is needed to vaporize 3.0 g of hexane? Show your work. **(3 marks)**

c. What is the molar heat of vaporization of ethanol based on the given information? Show your work. **(3 marks)**

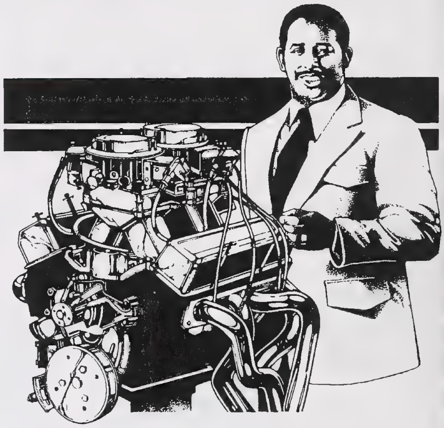
6. An experiment is performed where a 72.6 g piece of titanium metal is heated to 98.2°C in a boiling water bath. The titanium is then quickly transferred into 100.0 mL of calorimeter water at 23.5°C. The final temperature of the mixture in the calorimeter reaches 29.4°C.

   a. List two assumptions that you would have to make in order to calculate the specific heat capacity of titanium. **(2 marks)**

   b. Calculate the experimental specific heat capacity of the titanium sample. **(4 marks)**

MODULE SUMMARY

In this module you have learned about heat energy and its transformations. This area of chemistry is called thermodynamics. You have discovered that physical and chemical changes in heat content can be measured experimentally by using a device called a calorimeter. You have begun to see the connection between chemical bonds and their relative energies and you have discovered that the human system and the mechanical system have many similarities in energy changes. From the knowledge obtained in this module you have been able to make the invisible – energy – a little more visible.



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Final Module Assignment

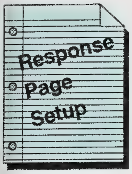
Review the Evaluation information found in the introductory pages of this module.

It is important to number and clearly identify each page with the following information at the top:

Chemistry 30 – Module 1   Final Module Assignment   Page #   Name and ID#

Be sure to write legibly. Leave a wide left margin and number all of your pages.

Part A: Multiple Choice



Read each question carefully and decide which of the choices best completes the statement or answers the question. Place the number of each question in a vertical column and place your answer (A, B, C, or D) beside each number. Each question is worth one mark. (Total = **5 marks**)

1. In a refrigerator, water is cooled from 36.0°C to –10.0°C. The water undergoes a change in

   A. kinetic energy only
   B. potential energy only
   C. translational energy only
   D. both kinetic and potential energy

2. When steam at 100°C condenses, the energy released results mainly from the formation of

   A. ionic bonds
   B. covalent bonds
   C. intermolecular bonds
   D. bonds between nucleons

3. When the three types of energy changes are arranged in order of decreasing molar enthalpy values, the order is

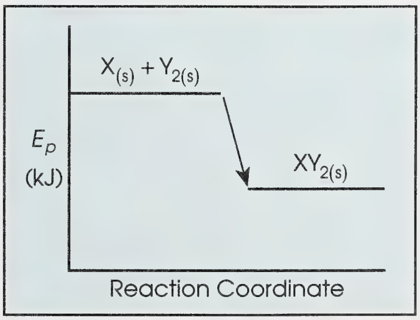
   A. phase, chemical, nuclear
   B. chemical, phase, nuclear
   C. nuclear, phase, chemical
   D. nuclear, chemical, phase

4. An exothermic reaction occurs in a calorimeter. The water of the calorimeter

   A. absorbs heat and a rise in temperature is observed
   B. absorbs heat and a drop in temperature is observed
   C. releases heat and a rise in temperature is observed
   D. releases heat and a drop in temperature is observed

5. The statement that best explains the data represented in the diagram on the right is that ΔH is

   A. positive and the reaction is exothermic
   B. negative and the reaction is exothermic
   C. negative and the reaction is endothermic
   D. positive and the reaction is endothermic



Part B: Written Response

1. Perform the following investigation. Submit your investigation report along with the rest of your module assignment.

Investigation: Specific Heat Capacity of Canola Oil

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Carefully follow the directions given for this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

Problem

What is the specific heat capacity of a canola oil sample?

Guidelines

- Read the entire investigation, including the questions, before starting the procedure.
- You will need about 15 to 20 g of canola oil (any brand, about four teaspoons) per trial.
- You may use any materials normally found in a school laboratory. If you are working at home you may need a measuring cup besides other materials that you may wish to use.
- You will probably find it easier to perform your procedure if you keep the oil separate (in a plastic bag) from the calorimeter water.

Caution

- **Do not heat** any materials directly in your polystyrene calorimeter. Use only a water bath to heat the materials you use.
- You may wish to use ice to cool some of the substances you use in order to get a greater initial temperature difference.
- You may find it easier to measure the mass of oil required by difference (mass of oil + container minus the mass of oil + container once an oil sample has been removed).

a. List all the materials you will need to complete this investigation. **(2 marks)**

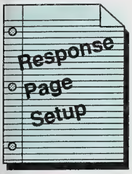
b. Write a procedure in step form to solve the problem. **(4 marks)**

c. Make an evidence table, carry out the procedure, and record your observations. **(2 marks)**

d. For your analysis, show all the calculations necessary to determine the specific heat capacity of the oil using the data you collected. Indicate your average *c* value. **(4 marks)**

e. List one assumption you made in your calculations. **(1 mark)**

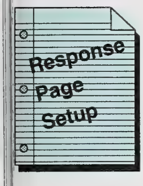
f. State two possible sources of error. **(2 marks)**



Reproduce the science skills assessment box after your response to this question. Remember to indicate your evaluation of your skill level for each identified science skill. Leave a space for the teacher assessment.

Self:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐
Teacher:	A. ☐	B. ☐	C. ☐	D. ☐	E. ☐	F. ☐

2. A mass of 20 g of ice at –15°C undergoes an energy change and ends up as water at 92°C. Plot a heating curve to show this change. **(3 marks)**



In this question, you do not have to use graph paper. However, draw both axes with a ruler and label your cooling curve properly. Each axis should be between 5 cm and 8 cm in length.

3. An equal amount of heat is added to equal masses of lead and copper. Explain which material would have a greater increase in temperature. **(2 marks)**

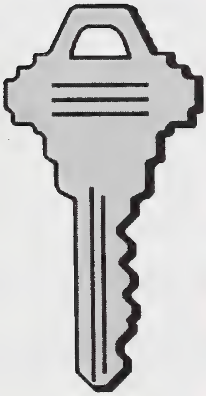
To ensure that all of your work has been completed in a satisfactory manner, check off the items in the following list:

- ❑ Section 1 Assignment has been completed.
- ❑ Section 2 Assignment has been completed.
- ❑ The Final Module Assignment has been completed.
- ❑ Your responses are organized and neat, with room for teacher comments.
- ❑ All your response pages are numbered consecutively and identified with this heading.

Chemistry 30 – Module 1 Section # Assignment Page # Name and ID #

Submit **only** your **assignment response pages** for evaluation.

Appendix



Glossary

Science Skills

Activities

Extra Help

Enrichment

Glossary

ADP (adenosine diphosphate): an organic molecule which traps energy

ATP (adenosine triphosphate): an organic molecule which stores energy in living things

bomb calorimeter: thick-walled calorimeter that can withstand high pressure

calorimeter: a device used for measuring energy changes

cellular respiration: the process by which energy is obtained in organisms from the reaction of compounds such as glucose

closed system: a system which allows energy transfer but not mass transfer

energy: the ability to do work

endothermic: absorbing heat from surroundings

enthalpy changes: changes in the total heat content of a system

enzymes: chemicals which increase the reaction rate of a chemical process

exothermic: releasing heat to the surroundings

fractional distillation: a physical process during which molecules of different sizes are separated as a result of their different boiling points

fractions: different groups of compounds collected in different trays of the fractionating column

glucose: an organic molecule used as an energy source by living things

isolated system: a system in which neither energy nor matter can move in or out of the system

mitochondria: the structures in a cell where energy is produced

qualitative: observations of what is present, made without measurements

quantitative: observations of what is present, made with measurements

science skills: processes and their component skills required to obtain a solution to a particular problem

specific heat capacity: amount of heat needed to raise the temperature of a unit mass of a substance by one degree Celsius

systems: groups of units working as a whole

thermal: changes related to heat energy

thermogram: an infrared picture which shows different levels of heat energy

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

A Framework for Scientific Problem-Solving Skills*

* This information is provided by Alberta Education, Evaluation Branch.

A. Initiating and Planning

- identify and clearly state the problem or issue to be investigated
- differentiate between relevant and irrelevant data or information
- assemble and record background information
- identify all variables and controls
- identify materials and apparatus required
- formulate questions, hypotheses and/or predictions to guide research
- design and/or describe a plan for research or to solve the problem
- prepare required observation charts or diagrams

B. Collecting and Recording

- carry out and modify the procedure if necessary
- organize and correctly use apparatus and materials to collect reliable experimental data
- accurately observe, gather, and record information or data according to safety regulations (e.g., WHMIS) and environmental considerations

C. Organizing and Communicating

- organize and present data in a concise and effective form (themes, groups, tables, graphs, flow charts, and Venn diagrams)
- communicate data more effectively, using mathematical and statistical calculations where necessary
- express measured and calculated quantities to the appropriate number of significant digits and use appropriate SI units for all quantities

D. Analysing

- analyse data and information for trends, patterns, relationships, reliability, and accuracy
- identify and discuss sources of error and their effect on results
- identify assumptions, attributes, bias, claims, or reasons
- identify main ideas

E. Connecting, Synthesizing, and Integrating

- predict from data or information
- formulate further testable hypotheses supported by the knowledge and understanding generated
- identify alternatives for consideration
- propose and explain interpretations or conclusions
- develop theoretical explanations
- relate the data to laws, principles, models, or theories identified in background information
- answer the problem investigated
- summarize and communicate finding
- decide on a course of action

F. Evaluating the Process or Outcomes

- establish criteria to judge data or information
- consider consequences and perspectives
- identify limitation of the data and information, interpretations, or conclusions as a result of the experimental/research/project/design, processes, or methods used
- suggest alternatives and consider improvements to experimental technique and design
- evaluate and assess ideas, information, and alternatives

CRITERIA FOR ASSESSING SCIENTIFIC PROBLEM-SOLVING SKILLS

A. INITIATING AND PLANNING

Level 1	Level 2	Level 3	Level 4	Level 5
• Proposes a simple problem statement when initiated to do so	• Proposes a simple problem statement	• Proposes a problem to be investigated	• Clearly states the purposes and problem to be investigated	• Performs at a level beyond level 4
• Background information must be supplied	• Background information is supplied from teacher or student's own experience	• Background supplied by teacher, reference material, or student's own experience	• Prepares the necessary background information from references, research, discussion, and/or past experience	• Characteristic of work done at college or university level
• Identifies those things that change and those that stay the same	• Identifies variables and controls	• Identifies controls, manipulated variables, and responding variables	• Identifies the controls and variables	
• Guesses about the outcomes	• Makes 'educated' guesses	• Makes a prediction and/or suggests a simple hypothesis	• Forms an appropriate hypothesis and prediction • Designs an investigation	
• Identifies simple materials and equipment to be used	• Identifies materials and equipment to be used • Is able to assemble simple apparatus	• Identifies the materials and equipment to be used • Assembles simple apparatus	• Identifies and names the materials and equipment to be used • Assembles and designs or modifies simple apparatus	
• Follows directions as provided	• Follows directions as provided • Is able to write simple procedural statements	• Develops and organizes a simple written procedure	• Designs and writes descriptions of procedures that are clear and detailed	
	• Prepares observation charts, tables, and diagrams as directed by teacher	• Prepares observation charts, tables, diagrams, graphs • Performs calculations as outlined by teacher	• Prepares observation charts, diagrams, and graphs • Performs necessary calculations	

B. COLLECTING AND RECORDING

Level 1	Level 2	Level 3	Level 4	Level 5
• Follows a simple procedure	• Follows a simple procedure	• Follows a given procedure and is able to suggest modifications when asked to do so	• Follows a given procedure and modifies the procedure when necessary	• Performs at a level beyond level 4
• Correctly uses apparatus and materials as directed by teacher	• Correctly uses apparatus and materials with little teacher assistance	• Correctly uses apparatus and materials with infrequent modification	• Consistently uses standard apparatus and materials correctly	• Characteristic of work done at college or university level
• Collects data using concrete, tangible objects	• Collects tangible objects • Carries out simple measurements	• Accurately collects data	• Accurately collects relevant data	
• Records data in sentence form or in simple charts that have been constructed	• Records data in numerical and non-numerical form • Is able to use and construct simple charts	• Records relevant data including the correct units with respect to measured data	• Records relevant data using the appropriate units	
• Is aware of safety and environmental concerns • Follows stated safety procedures	• Is aware of safety and environmental concerns • Follows stated safety procedures	• Shows appropriate safety and environmental concerns in the use, care, and maintenance of materials and apparatus	• Demonstrates appropriate standards of safety	
		• Is able to locate appropriate safety regulations • Actively participates in teacher-directed discussion of safety and environmental issues	• Is able to suggest modifications to procedures to minimize environmental damage	

C. ORGANIZING AND COMMUNICATING

Level 1	Level 2	Level 3	Level 4	Level 5
• Organizes data in sets of concrete objects	• Organizes data in sets of objects	• Organizes data in the form of sets, themes, and/or tables	• Organizes data accurately	• Performs at a level beyond level 4
	• Provides a basis for the organization of data sets • Constructs simple graphs to represent the data	• Provides a basis for and suggests alternatives for the organization of data • Is able to construct graphs and/or tables to represent the data	• Is able to represent data using appropriate graphs and tables	• Characteristic of work done at college or university level
	• Performs basic mathematical calculations	• Performs basic mathematical calculations	• Performs relevant and required mathematical calculations	
	• Identifies, with teacher assistance, errors and inaccuracies	• Identifies errors and discrepancies in data • Takes part in teacher-directed discussion of scientific inaccuracies	• Expresses measured and calculated quantities to correct degree of precision	

D. ANALYSING

Level 1	Level 2	Level 3	Level 4	Level 5
• Correctly identifies patterns within the data	• Assesses patterns and trends that are conceptually presented by the data	• Assesses patterns, trends, and simple relationships	• Assesses patterns, trends, and relationships resulting from collected and manipulated data	• Performs at a level beyond level 4
• Identifies, with teacher assistance, relationships	• Identifies simple cause and effect relationships	• Identifies cause and effect relationships	• Identifies the sources of error in data collection and manipulation	• Characteristic of work done at college or university level
	• Identifies, with teacher assistance, the sources of error in data collection and manipulation	• Identifies the sources of error in data collection and manipulation	• Expresses accuracy qualitatively and/or quantitatively (percent difference), where applicable • Identifies the assumptions relating to measurement and/or analysis	
	• Identifies, with teacher assistance, the effect of errors on results	• Suggests amendments to procedures and/or data manipulation in order to rectify results	• Determines the reliability of the data	

E. CONNECTING, SYNTHESIZING, AND INTEGRATING

Level 1	Level 2	Level 3	Level 4	Level 5
• Provides a simple but not necessarily appropriate answer to the problem investigated based on results obtained	• Provides a simple answer that is appropriate for the problem investigated and results obtained	• Provides an appropriate answer to the problem investigated based on results obtained	• Provides a qualified answer to the problem investigated	• Performs at a level beyond level 4
	• Attempts to relate results to knowledge that is not specifically related to scientific theories or laws	• Relates results, with teacher assistance, to applicable theories and/or laws	• Relates the data to laws, principles, models, or theories identified in background information and/or in broader context	• Characteristic of work done at college or university level
			• Proposes and explains interpretations or conclusions • Develops theoretical explanations	

F. EVALUATING THE PROCESS OR OUTCOMES

Level 1	Level 2	Level 3	Level 4	Level 5
• Attempts to explain results to the problem investigated	• Attempts to explain results to the problem investigated	• Is able to explain the results obtained in light of the problem being investigated	• Evaluates the prediction and concepts	• Restricts, revises, or replaces an unacceptable scientific concept
	• Attempts to draw conclusions where applicable and when prompted	• Draws conclusions and attempts to explain them	• Draws conclusions and attempts to explain them	• Establishes criteria to judge the design, prediction, and concepts
		• Discusses the limitations of the data collected, interpretations, and/or conclusions	• Identifies limitations of the data and information, interpretations, or conclusions, as a result of the design of the experiment, research, or project	• Considers consequences and perspectives • Evaluates assumptions and effects of bias
		• Discusses, when prompted, the validity of results • Discusses, when prompted, alternatives and/or improvements to the experimental design	• Suggests alternatives and considers improvements to experimental technique and design	• Evaluates the total investigation in terms of reliability and validity

Science Skills Spreadsheet

You may reproduce this spreadsheet as required for use in this course.

CHARTING GROWTH IN SCIENCE SKILLS																
Feedback from Assignments			Initiating and Planning		Collecting and Recording		Organizing and Communicating		Analysing		Synthesizing and Integrating		Evaluating			
Module	Section	Question	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher	Self	Teacher		

Diploma Examination General Information

Format of the Chemistry Examination

The time allotted to write the diploma examination is two and one-half hours. An additional 30 minutes is available, giving you up to three hours to complete the examination. The Chemistry 30 examination has both machine-scorable questions (multiple-choice and numerical-response) and written-response questions.

A separate data booklet is provided for the Chemistry 30 examination. The examination has tear-out pages for rough work.

Note: The Chemistry diploma examination contains questions that require you to combine concepts from more than one unit of study.

- Written-response questions will be evaluated on how well the answer is communicated.
- Some questions will include concepts from more than one of the core concepts.
- Written-response questions will require you to see relationships among concepts learned.
- Some questions will require you to apply what you learned in new contexts.
- Written-response questions may require you to write balanced chemical reaction equations including correct states of matter.
- Numerical answers are to be rounded only once, at the end of the question. Intermediate numbers are to be used as displayed on the calculator.
- The terms *oxidation number* and *oxidation state* are considered to have the same meaning.
- A scientific calculator is required to write the examination. The only student programmed function allowed is the quadratic equation. (See the separate heading Use of Calculators on Alberta Education Diploma Examinations.)

Evaluation of Written Responses

You are given credit for responses that are on topic, clear, concise, well written, and demonstrate the conventions of scientific language. Your assessment is based on three main criteria:

- Your response should answer the question asked and appropriately use the concepts you learned in Chemistry 30. The "box" method of stoichiometry is **not** an acceptable method of response.
- Your response should be clear and logical, and organized in a meaningful manner. "Shorthand" should not be used because your notations may not be understood by all markers.
- Your response should use conventions of scientific language accurately. Proper terminology should be used; for example, pH **not** Ph, molar heat (enthalpy) of reaction **not** reaction heats, etc.

Use of Calculators on Alberta Education Diploma Examinations

Since the data provided for writing the diploma examination in chemistry does not include information such as logarithms and trigonometric functions, you will need to use a scientific calculator to write your exam.

A scientific calculator is considered to be a hand-held device designed primarily for mathematical computations. Included in this definition are those scientific calculators having graphing capabilities, built-in formulas, mathematical functions, or other programmable features.

To ensure consistency with provincial *Programs of Study* and fairness for all students, Alberta Education expects you to use a scientific calculator, as previously defined, when you are writing diploma examinations in mathematics, chemistry, and physics. Examinations are constructed to ensure that the use of particular models of calculators neither benefits nor disadvantages any individual.

- In preparation for calculator failure, you may bring an extra calculator and batteries into the exam.
- During the exam, the supervising teacher will ensure that
  - your calculator falls within the definition provided
  - the calculator operates in silent mode
  - you do not share your calculator with anyone
  - you do not bring external devices (a manual, a printed or electronic card, printer, memory expansion chip or card, external keyboard, or any directions outlining the operational procedures for your scientific calculator) to support your calculator into the examination room

Examination Rules for Grade 12 Diploma Examinations

1. **Admittance to the Examination Room**
   You cannot enter or leave the examination room without the consent of the supervising teacher.

2. **Student Identification**
   You must present identification that includes your signature and photograph. One of the following documents is acceptable: driver's licence, passport, or student identification card. You must not write an examination under a false identity or knowingly provide false information on an application form.

3. **Identification on Examinations**
   You must not write your name or the name of your school anywhere in or on the examination booklet other than on the back cover.

4. **Time**
   You must write an examination during the specified time and may not hand in a paper until at least one hour of the examination time has elapsed. If you arrive more than one hour after an examination has started you will not be allowed to write the examination. If you arrive late but within the first hour of an examination sitting, you must be allowed to write only at the discretion of the supervising teacher.

5. **Discussion**
   You must not discuss the examination with the supervising teacher unless the examination is incomplete or illegible. You must not talk, whisper, or exchange signs with one another.

6. **Answer Sheets**
You must use an HB pencil to record your answers on the machine-scorable answer sheets.

7. **Written Responses**
All work for the written-response sections of the diploma examinations must be done in the examination booklet.

8. **Material Exchanges**
You must not copy from other students or exchange material. Notes in any form – including those on papers, in books, or stored in electronic devices – must not be brought into the examination room. Calculator programs designed to perform mathematical computations or those designed to assist you in graphing are not classified as notes.

9. **Material Allowed**
A separate data booklet is provided for the chemistry examination. You are expected to provide your own writing materials, including pens and HB pencils, calculators, or other necessary instruments. Tear-out pages for rough work are provided in each chemistry examination booklet.

10. **Translation Dictionaries**
You are not allowed to use a translation dictionary to write your exam.

Guidelines for Significant Digits, Manipulation of Data, and Rounding in the Chemistry Examination

Significant Digits

1. For all nonlogarithmic values, regardless of decimal position, any of the digits 1 to 9 is a significant digit; 0 may be significant, for example,

   123 0.123 0.002 30 2.30×10^3
   all have 3 significant digits

2. Leading zeros are not significant, for example,

   0.12 and 0.012 have two significant digits

3. Trailing zeros to the right of the decimal are significant, for example,

   0.123 00 and 20.000 have five significant digits

4. Zeros to the right of a whole number are considered to be ambiguous. **The Student Evaluation Branch considers all trailing zeros to be significant**, for example,

   200 has three significant digits

5. For logarithmic values, such as pH, any digit to the left of the decimal is **not** significant, for example,

   a pH of 1.23 has two significant digits, but a pH of 7 has no significant digits

Manipulation of Data

1. When adding or subtracting measured quantities, the calculated answer should be rounded to the same degree of precision as that of the least precise number used in the computation **if this is the only operation**, for example,

$$\begin{array}{rl} 12.3 & \text{(least precise)} \\ 0.12 & \\ \underline{12.34} & \\ 24.76 & \text{The answer should be rounded to 24.8.} \end{array}$$

2. When multiplying or dividing measured quantities, the calculated answer should be rounded to the same number of significant digits as are contained in the quantity with the fewest number of significant digits **if this is the only operation**, for example,

$$(1.23)(54.321) = 66.814\ 83 \qquad \text{The answer should be rounded to 66.8.}$$

3. When a series of calculations is performed, the answer should not be rounded off based upon interim values, for example,

$$(1.23)(4.321)/(3.45 - 3.21) = 22.145\ 125 \qquad \text{The answer should be rounded to 22.1.}$$

Rounding

1. When the first digit to be dropped is less than or equal to 4, the last digit retained should not be changed, for example,

1.2345 rounded to three digits is 1.23

2. When the first digit to be dropped is greater than or equal to 5, the last digit retained should be increased by one, for example,

12.25 rounded to three digits is 12.3

Directing Words

- **Discuss** – The word "discuss" will not be used as a directing word on the chemistry diploma examination because it is not used consistently to mean a single activity. It can mean to debate, i.e., present arguments both pro and con; to investigate, i.e., present in detail the factual information about a topic; or simply to talk about a subject.

The following words are more specific in meaning. Carefully read the expectations for each directing word.

- **Contrast/Distinguish** – Point out the *differences* between two things that have similar or comparable natures.

- **Compare** – Show the character or relative values of two things by pointing out their *similarities* and *differences*.

- **Conclude** – State a logical end based on reasoning and/or evidence.

- **Criticize –** Point out the *merits* and *demerits* of an item or issue.
- **Define –** Provide the essential qualities or meaning of a word or concept. Make a meaning distinct and clear by marking out the limits.
- **Describe –** Give an account of in words; or represent by a figure or model, or picture the characteristics.
- **Design/Plan –** Construct a plan; i.e., a detailed sequence of actions for a specific purpose.
- **Enumerate –** Specify one by one or list in concise form and according to some order.
- **Evaluate –** Give the significance or worth of something by identifying the good and bad points or the advantages and disadvantages.
- **Explain –** Make clear what is not immediately obvious or entirely known; give the cause of or reason for; make known in detail.
- **How –** Show in what manner.
- **Hypothesize –** Form a tentative proposition intended as a possible explanation for something observed, i.e., a possible cause for a specific effect. The proposition should be testable logically and/or empirically.
- **Identify –** Recognize and select as having characteristics of.
- **Illustrate –** Make clear by giving an example. The form of the example must be specified in the question, i.e., word description, sketch, or diagram.
- **Infer –** Form a generalization from sample data; arrive at a conclusion by reasoning from evidence.
- **Interpret –** Tell the meaning of; present information in a new form that adds meaning to the original data.
- **Justify/Show How –** Show reasons for, or give facts that support a position.
- **Outline –** Give, in an organized fashion, the essential parts of. The form of the outline must be specified in the question, i.e., lists, flow charts, concept maps.
- **Predict –** Tell in advance on the basis of empirical evidence and/or logic.
- **Prove –** Establish the truth, validity, or genuineness of something by giving factual evidence or logical reasons.
- **Relate –** Show logical or causal connection between.
- **Solve –** Give a solution, i.e., an explanation in words and/or numbers, for a problem.
- **Summarize –** Give a brief account of the main points.
- **Trace –** Give a step-by-step description of the development of.
- **Why –** Show the cause, reason, or purpose for which.

Preparing to Write a Science Diploma Examination – What you should do before the examination!

1. Prepare a course review schedule.

    - Design your schedule for the two-week period (minimum) before the examination.

    - Divide the course material into sections and indicate on the schedule the time blocks to be devoted to each section.

        – Take into account the examination blueprint available from your teacher (*Diploma Examinations Program Information Bulletin* for the course). This blueprint indicates the relative importance (weighting) of each unit in the course. Note that course units are not equally weighted on the diploma examination.

        – Take into account units/concepts that you find most difficult, i.e., allocate more time for the review of these.

2. Obtain and review examination schedules, rules, and policies.

    - Record the time and place of writing.

    - Note minimum and maximum writing times permitted.

    - Prepare to remain in the examination room for at least 2.5 h (Kleenex, cough drops, etc.).

    - Identify materials allowed for writing each examination, such as pencils, pens, calculators, mathematical intruments, and a clear plastic ruler.

3. Identify and collect examples of each type of question that will be asked.

    - Review the format of previous diploma examinations.
    - Learn the meanings of the key "directing" words.

4. Make summaries and point form outlines.

    - Distinguish between major concepts and factual details.
    - Identify essential skills that can be assessed on paper and pencil tests.
    - Review investigation results and procedures.
    - Identify connections between investigation reports, your notes, and your textbook.
    - Anticipate examples of connections between concepts and the "real world."
    - Prepare a glossary of important subject terminology.
    - Review formulas and equations and data tables.
    - Link each formula or equation with a calculation done on a previous test or assignment.
    - Identify any restriction on the use of each formula or equation.

5. Use memory aids such as the following.

    - Colour code, underline, highlight, or jot key words in margins.
    - Number points to be memorized.
    - Group word and idea associations.
    - Read aloud key words, expressing key words in your own words.

Suggestions for Students Writing a Chemistry Diploma Examination – What you should know when writing the examination!

1. Do not be afraid to answer each question even if you are not sure of the correct solution to the problem. A penalty is NOT given for guessing on the machine-scored section of the exam. Partial marks are often awarded for incomplete answers in the written-response section of the exam.

2. If you are stuck on a question, mark the alternatives that you know are incorrect and choose from the ones that are left using logical guessing strategy. Think of the questions as challenges and cultivate a positive attitude about your ability to answer them.

3. Scan the written-response, multiple-choice, and numerical-response sections of the examination before answering the questions. A question in one section of the examination may jog your memory about a question in another section.

4. When first reading a multiple-choice question, locate and circle key words to help clarify the meaning of the question. Then hide the alternatives and try to formulate an answer of your own. Your answer may be very close to the correct alternative.

5. If a multiple-choice question involves a calculation, do the calculation and select the alternative that is closest to your answer. A multiple-choice calculation is usually short. If you cannot do it in five minutes, your method is either inappropriate or incorrect. Go on.

6. Diagrams on examinations are often labelled with numbers or letters. It may be useful to write in the names of the labelled structures or features that you can identify.

7. When reading graphs, use a clear plastic ruler to more accurately extrapolate or interpolate data.

8. Have a good reason for changing an answer. Do not change an answer on a hunch. Do not waste your time looking for patterns of As, Bs, Cs, or Ds in multiple-choice answers. There are none.

9. You may not have time to write and edit a complete rough copy for each written-response question, but you should prepare an outline of your answer and use it as a guide when writing your good copy.

10. When completing a written-response question, keep in mind the reader of your response. The reader will want to know how well you

    - understand the problem or the mathematical/science concept
    - can correctly use the mathematics involved
    - can use problem-solving strategies and explain your answer and procedures
    - can communicate your solutions and mathematical/science ideas

11. Rewriting a statement of the question is often a good way to begin a written response. Conclude with a summary statement. Be sure you have clearly explained all assumptions and have verified your conclusions.

12. Keep track of the time and pace yourself. Put a check mark by items that you are uncertain about and return to them if there is time at the end of the examination.

Suggested Answers

Section 1: Activity 1

1. Scientists pose questions, make predictions or hypotheses based on scientific principles, and design and perform experiments to obtain answers to their questions.

2. Scientists evaluate their process by comparing their experimental results to the results they predicted.

3. The purpose is a general statement which describes the general intent of the investigation. The problem is a specific question, based on the purpose, that you intend to answer. The problem usually contains the manipulated variable that is being studied – the variable set by experimenter, and the responding variable – the resulting outcome.

4. The experimental design states the general process by which the problem will be solved. The procedure outlines specific steps and measurements followed in solving the problem.

5. a. The types of variables and their definitions are given in Table 1.4 on page 31 of *Nelson Chemistry*.

   b.

Type of Variable	Identity in Stain Removal Investigation
manipulated	type of cleaning solution
responding	degree of stain removal
controlled	volume of cleaning solution, length of soaking time, amount of scrubbing, type of soft drink, water

6. Evidence gathered is empirically-based on the senses. There are no inferences or conclusions made. The analysis, however, does make inferences for explaining observations, making connections, etc.

7. The steps to be performed are indicated by check marks.

8. Three possible evidence tables are given with possible assessments.

EXAMPLE EVIDENCE TABLE 1

Substance	Observations
aluminum foil	The silver solid turned red when put into the beaker. Rust was formed.
copper chloride solution	The blue solution bubbled when the foil was put in.

Assessment Comments:

- The observations are organized in a table, which is good.
- The copper chloride name is not correct – it should be copper(II) chloride.
- There are not any observations specified before and after the reaction takes place.
- There are no quantitative observations.
- There is an inference in the table that rust was formed. This is not an observation.

Teacher Assessment:

Collecting and recording – level $\boxed{2}$ Organizing and communicating – level $\boxed{2}$

EXAMPLE EVIDENCE TABLE 2

Substance	Observations
aluminum foil	Before the reaction the 10 cm × 10 cm foil was silvery in colour.
copper(II) chloride	Before the reaction the copper(II) chloride was a blue solid weighing 5 g.
water	The water was a clear liquid before the reaction.
aluminum foil in solution	The aluminum foil started to smoke when it was placed in the solution. A reddish-brown solid appeared on the foil's surface.
copper(II) chloride solution	When the foil was added, the solution started to bubble around the edges of the foil and steam rose up.

Assessment Comments:

- Observations are more complete; there are some quantitative observations, but not many.
- The table is more organized with "before" and "after" observations.
- Terms are used correctly.

Teacher Assessment:

Collecting and recording – level $\boxed{3}$ Organizing and communicating – level $\boxed{3}$

EXAMPLE EVIDENCE TABLE 3

Before placing the aluminum foil into the solution –

Substance	Observations	
	Quantitative	Qualitative
aluminum foil	10 cm × 10 cm 0.5 g	silvery solid, shiny in appearance
copper(II) chloride	5 g (5 mL or 1 tsp.)	blue granular solid, dull appearance; when placed in water – initially was green but when dissolved, turned blue
water	23.5°C 100 mL	clear, colourless liquid

After placing the aluminum foil into the solution –

Substance	Observations
aluminum foil	10 s – aluminum foil appeared to be releasing steam when mixed in the $CuCl_{2(aq)}$ 20 s – small patches of reddish-orange solid appeared on the surface – some small patches of black solid 50 s – surface of foil almost entirely covered with red solid – still a few patches of black and silver colour
copper(II) chloride solution	10 s – some steam starting to appear to rise from solution; some bubbles 20 s – more bubbling of solution around edges of foil; temperature increased to 25.5°C 250 s – fairly vigorous bubbling around the edges of foil; solution increased to 41.8°C

Assessment Comments:

- The table gives a very complete description of events.
- There are many examples of qualitative and quantitative observations.
- Descriptions are very clear.
- The table is well-organized.

Teacher Assessment:

Collecting and recording – level $\boxed{4}$ Organizing and communicating – level $\boxed{4}$

9. The reaction is exothermic because the temperature on the thermometer went up (increased). This shows that heat was released to the surroundings.

10. The orange-red solid was solid copper.

11. Evidence for a chemical change include a change in colour and the release of heat.

12. Your assessments may vary. Teacher assessments for each example table are given under each evidence table in question 8.

13. a. The skills will be practised within the student module booklet – in investigations, some analysis questions, etc.

    b. The science skill icon in the left margin indicates when science skills are to be practised.

    c. The skills focused on are checked in the icon.

14. The science skills assessment icon will be in the left margin of any questions where science skills are being assessed.

15. The level assessment will not affect your grade. The purpose of the assessment is to help you improve in your self-assessment and to help you grow in your science skills.

16. Complete information on the description of science skills is found in the Appendix of Module 1.

17. You will gain positive feedback on your progress and growth throughout the course.

18. a. You record your student assessment (your own) and the teacher assessment on the spreadsheet.

    b. Using one spreadsheet gives you an idea of how much you have improved throughout the course. It also shows you areas in which you can improve.

Section 1: Activity 2

1. The three forms of energy illustrated in the graphic are chemical, mechanical, and heat energy.

2. **Textbook question 1:**

   Answers will vary. Examples may be as follows.

   Two energy-consuming devices that are essential are a cooking range and a car. Two devices that are practical, efficient, and convenient are a television and a desk lamp; two devices that are non-essential are a stereo sound system and an electric can opener.

   Textbook question 2:

Example	Useful Form of Energy
cooking range	heat
car	mechanical
television	light, sound
desk lamp	light
stereo sound system	sound
electric can opener	mechanical

   Textbook question 3:

Example	Energy Source	Natural Source
cooking range	chemical, electrical	water, fossil fuels
car	chemical	fossil fuels, plants
television	electrical	water, fossil fuels
desk lamp	electrical	water, fossil fuels
stereo sound system	electrical	water, fossil fuels
electric can opener	electrical	water, fossil fuels

   Note: There are other possibilities not listed.

   Textbook question 4:

   Three energy-conserving strategies include

   - using the energy-saving cycle when using a dishwasher
   - avoiding use of electrical lights during daylight
   - using car pools for travelling

Textbook question 5:

Solar and geothermal energy do not create pollution when the energy is being harnessed from them. Also, they do not involve as expensive a mechanism for their use as do fossil fuels or nuclear fuels.

3. The processes can be classified as follows:

a. exothermic b. exothermic c. endothermic d. endothermic

4. The kinetic theory can be used to explain the behaviour of smoke as follows: Smoke is made up of tiny particles. The particles collide with air molecules around them, causing their motion to be erratic. This random motion is called Brownian motion.

5. The differences can be explained as follows:

Temperature	Kinetic Energy	Heat
• is a measure of the average kinetic energy of the molecules in a system	• is the energy due to molecular motion	• is energy that is transferred between substances

6. A change in the **temperature** of a substance, as measured by a thermometer, is associated with a change in the average **kinetic energy**, ΔE_k, of the particles in the substance.

7. **delta** (means *change in*) **symbol for energy**

$$\Delta E_k$$

symbol for kinetic

The complete symbol means *change in kinetic energy*.

8. **Textbook question 6:**

The specific heat capacities for the three states of water are as follows:

- ice – $c_{H_2O}(\text{solid}) = 2.01 \dfrac{\text{J}}{\text{g} \bullet {}^\circ\text{C}}$
- water – $c_{H_2O}(\text{liquid}) = 4.19 \dfrac{\text{J}}{\text{g} \bullet {}^\circ\text{C}}$
- steam – $c_{H_2O}(\text{gas}) = 2.01 \dfrac{\text{J}}{\text{g} \bullet {}^\circ\text{C}}$

These constants would be used to calculate energy changes involving changes in temperature. For example, if an energy calculation involving ice changing in temperature was performed, the specific heat capacity for ice, $2.01\ \text{J/g} \bullet {}^\circ\text{C}$, would be used in the formula $q = mc\Delta t$. The value for $c_{H_2O}(\text{liquid})$, $4.19\ \text{J/g} \bullet {}^\circ\text{C}$ would be used in calculations involving liquid water and $c_{H_2O}(\text{gas})$, $2.01\ \text{J/g} \bullet {}^\circ\text{C}$ would be used in heat calculations involving steam.

Textbook question 7:

$$q = mc\Delta t$$
$$= 1.50 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 80.7^\circ\text{C}$$
$$= 507 \text{ kJ}$$

The quantity of heat is 507 kJ.

Remember to check your significant digits.

Textbook question 8:

$$q = mc\Delta t$$
$$= 100 \text{ kg} \times \frac{2.01 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 110^\circ\text{C}$$
$$= 2.21 \times 10^4 \text{ kJ}$$

The quantity of heat is 2.21×10^4 kJ.

Textbook question 9:

$$q = mc\Delta t$$
$$= 2.5 \text{ kg} \times \frac{0.86 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 335^\circ\text{C}$$
$$= 7.2 \times 10^2 \text{ kJ}$$

The amount of heat released is 7.2×10^2 kJ.

Textbook question 10:

$$q = mc\Delta t$$
$$250 \text{ kJ} = v \times \frac{3.7 \text{ kJ}}{\text{L} \bullet {}^\circ\text{C}} \times 10^\circ\text{C}$$
$$v = \frac{250 \text{ kJ}}{\frac{3.7 \text{ kJ}}{\text{L} \bullet {}^\circ\text{C}}(10^\circ\text{C})}$$
$$= 6.8 \text{ L}$$

The volume required is 6.8 L.

Textbook question 11:

a. $q = mc\Delta t$
$$= 100 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 35^\circ\text{C}$$
$$= 1.5 \times 10^4 \text{ kJ}$$

The quantity of heat obtained is 1.5×10^4 kJ.

b. $1.5 \times 10^4 \text{ kJ} = 15 \text{ MJ}$

$$\text{total cost} = \frac{15 \text{ MJ}}{\text{time}} \times \frac{0.351¢}{\text{MJ}} \times 1500 \text{ times}$$
$$= 7898¢$$
$$= \$78.98$$
$$= \$78$$

The cost is \$78 per year. (Using the unrounded value from Textbook Question 11. a., the cost would be \$77.)

Textbook question 12:

a. $q = mc\Delta t$
$$= 100 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 25^\circ\text{C}$$
$$= 1.0 \times 10^4 \text{ kJ}$$

The quantity of heat is 1.0×10^4 kJ.

b. $1.0 \times 10^4 \text{ kJ} = 10 \text{ MJ}$

$$\text{total cost} = \frac{10 \text{ MJ}}{\text{time}} \times \frac{0.351¢}{\text{MJ}} \times 1500 \text{ times}$$
$$= 5265¢$$
$$= \$52.65$$
$$= \$52$$

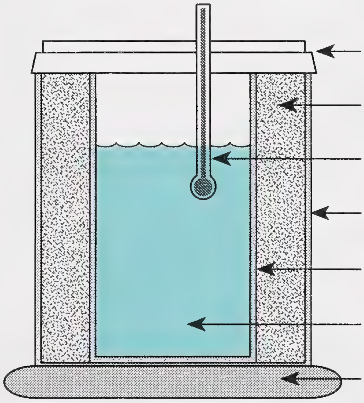
The cost is \$52 per year. (Using the unrounded value from Textbook Question 12. a., the cost would be \$55.)

c. Ecologically, solar heating is better as it does not contribute to pollution as other fuels do. It produces no carbon dioxide gas which is one of the main contributors to the greenhouse effect. Economically, it is more expensive because of the equipment involved.

Textbook question 13:

Most water heaters in Alberta use natural gas (methane), a non-renewable resource. Even some of the electrically heated water heaters get their energy from non-renewable resources such as coal used in some power plants.

9. Use a large tin can to house a smaller tin can. A juice can and a soup can work fine. Fill the space between the two cans with mineral wool or fibreglass insulation. It is very important that the insulation is non-flammable. Use a piece of polystyrene as a cover for the heater. Make a hole through the cover big enough to insert a thermometer through it.



10. The evidence table may look like the following:

Trial	Measurement	Reading
1	Mass of the water (g) Total mass of water + heater (g) Temperature of water before heating (°C) Final temperature of water after heating (°C) Final temperature of water after cooling (°C) Cooling time (min)	
2	Mass of the water (g) Total mass of water + heater (g) Temperature of water before heating (°C) Final temperature of water after heating (°C) Final temperature of water after cooling (°C) Cooling time (min)	

11. Answers will vary. Following is one example.

Trial	Measurement	Reading
1	Mass of the water (g) Total mass of water + heater (g) Temperature of water before heating (°C) Final temperature of water after heating (°C) Final temperature of water after cooling (°C) Cooling time (min)	100.0 169.5 24.8 60.1 57.0 10.0

12. Refer to the answer for question 9, Section 1: Activity 2.

13. Refer to the answer for question 11, Section 1: Activity 2.

14. To calculate the specific energy, use the relationship,

$$q = \frac{mc\Delta t}{\text{total mass of heater}}$$

$$= \frac{0.100\ \text{kg} \times \dfrac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 35.3^\circ\text{C}}{0.1695\ \text{kg}}$$

$= 87.3\ \text{kJ/kg}$ The specific energy is 87.3 kJ/kg.

To calculate the cooling rate use the relationship,

$$q = \frac{mc\Delta t}{\text{time}}$$

$$= \frac{0.100\ \text{kg} \times \dfrac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 3.1^\circ\text{C}}{10.0\ \text{min}}$$

$= 0.130\ \text{kJ/min}$ The cooling rate is 0.130 kJ/min.

15. The cooling rate of the heater is low and the specific energy is high, which suggests that the design is good. The design may be improved by eliminating one layer of can above the heat source. This could possibly be done by cutting out the bottom of the larger can, then wrapping the bottom of the inner can and the insulation with aluminum foil.

Section 1: Activity 3

1. The energy changes in the photograph can be summarized as follows:

$$\begin{matrix} \text{chemical} & \rightarrow & \text{kinetic} & \rightarrow & \text{heat} \\ \text{energy} & & \begin{pmatrix}\text{mechanical} \\ \text{energy}\end{pmatrix} & & \text{energy} \end{matrix}$$

2. a. The system is the collection of dancers. It is not a closed system because moisture is flowing from the system (from the dancers) into the surroundings.

   b. Yes, there is an enthalpy change in the system described. Some of the energy stored in the chemical bonds in the bodies of the dancers has been changed to heat energy and some of this heat has been released by the system to the surroundings.

3. The symbol used to represent enthalpy change is ΔH.

4. The total potential energy and kinetic energy represent the total enthalpy of this system.

5. a. A phase change is a change in the state (solid, liquid, or gas) of matter without a change in the chemical composition of the matter.

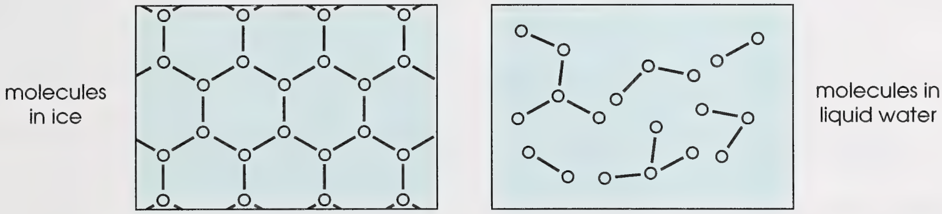
b. Two examples of a phase change are the following:

- ice melting in a rain barrel
- rubbing alcohol evaporating from your skin

6. The three endothermic phase changes are as follows:

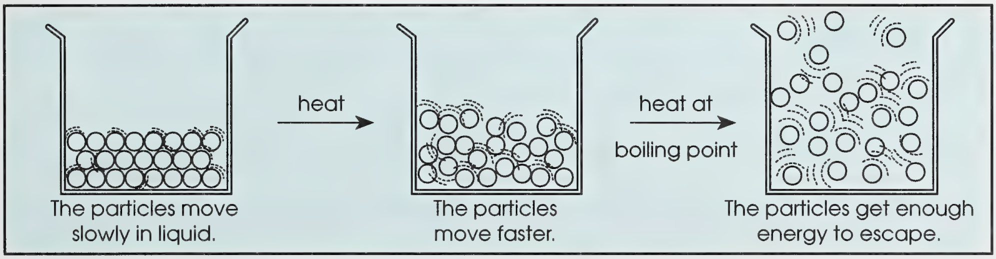
- **Melting or Fusion (solid → liquid)**

  Particles of matter in the solid state gain energy to overcome the attractive forces between the particles that hold them in their fixed positions. The gained energy is stored as potential energy within the particles. The particles in the liquid state can then slide past each other. They are still close together but don't have the fixed positions as in a solid state because the intermolecular forces that hold the molecules together are weaker.



- **Vaporization (Boiling) (liquid → gas)**

  As the molecules in a liquid gain energy, they move faster. When the temperature is close to the boiling point the molecules have enough energy to overcome the attractive forces holding them together and change to a gas form where the molecules are far apart and move faster. Therefore, a gas has no constant shape or volume.



- **Sublimation (solid → gas)**

  Sublimation involves a special situation when a relatively low pressure allows the particles in a system to gain enough energy to pass directly from solid to gas and separate quickly. An example of this type of change is illustrated by dry ice going from a solid to a vapour without becoming a liquid.

7. A heating curve is a graph of temperature versus time when heat energy flows into a system (endothermic change).

8. a.

Section	Potential Energy	Kinetic Energy	Temperature
AB	no change	increase	increase
BC	increase	no change	no change
CD	no change	increase	increase
DE	increase	no change	no change
EF	no change	increase	increase

b. The sections of the graph representing phase changes are section B to C (melting) and section D to E (vaporization).

9. Intramolecular bonds are broken and made to form new substances in a chemical change. In a phase change intermolecular bonds are broken or made, but only the physical state changes. No new substances are formed.

10. The potential energy of a system increases during an endothermic chemical change – heat energy is absorbed from the surroundings. The potential energy of a system decreases during an exothermic chemical change – heat energy is released to the surroundings. In both cases, the energy change of the system is equal to the energy change of the surroundings – the law of conservation of energy.

11. In a nuclear reaction, bonds within the nucleus between nuclear particles break, and new bonds form to make new arrangements of nuclear particles.

12. The order would be **c**, **b**, and **a** because a nuclear change involves the greatest amount of energy change and a phase change (ice melting) involves the least.

13. If each 1 cm in height is equal to 10 kJ/mol, then the nuclear change bar would have to be at least 10^{10} cm (10^8 m or 10^5 km or 100 000 km) high!

Section 1: Activity 4

1. a. Temperature and pressure determine the states of matter.

   b. When the factors are changed, a substance may undergo a phase change from one state to another.

2. a. The phase change is melting (fusion). Energy is absorbed; the change is endothermic.

   b. The phase change is boiling (vaporization). Energy is absorbed; the change is endothermic.

   c. The phase change is solidifying (freezing). Energy is released; the change is exothermic.

   d. The phase change is condensation. Energy is released; the change is exothermic.

   e. The phase change is sublimation. Energy is absorbed; the change is endothermic.

3. When one mole of water melts, 6.03 kJ of energy are absorbed. When one mole of water freezes, 6.03 kJ of energy are released. Therefore, the energy values for the opposite processes are equal.

4. The two heating curves would have the same basic shape, but the melting point and boiling point plateaus would be different in length and be in different positions, relative to the different melting and boiling points.

5. a. This statement means that when one mole of sodium changes from a solid to a liquid phase, 2.6 kJ of heat energy are absorbed.

   b. The symbol used to represent molar enthalpy is ***H***.

6. Since the water absorbs heat during these changes the surroundings will lose heat and therefore the temperature of the surroundings will drop.

7.

Variable	Description	Units
ΔH	change in heat or enthalpy change	kJ or J
n	amount of substance undergoing change	mol
H	heat for one mol of substance; is a constant obtained from a table	kJ/mol or J/mol

Note: Your textbook uses the symbol H with a subscript to indicate a molar enthalpy value. However, this is not a universal method. Other resources or textbooks may use the symbol ΔH with a subscript to indicate **any** enthalpy value, whether it's molar enthalpy or otherwise.

Example: *Nelson Chemistry* $\rightarrow H°_{fus} \leftarrow$ $\boxed{\text{molar enthalpy of fusion}}$ $\rightarrow \Delta H°_{fus} \leftarrow$ Other Textbooks

Your textbook does this to help you decide which units to use for different enthalpy values.

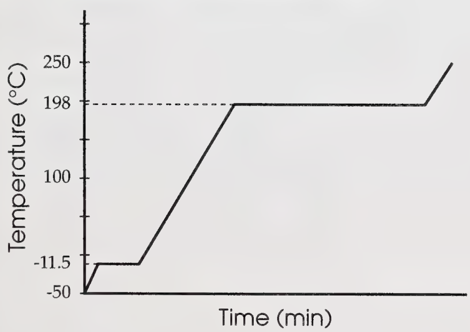
8. **Textbook question 15:**

$$\begin{aligned}\Delta H_{vap} &= nH_{vap}\\ &= 100\ \text{g} \times \frac{1\ \text{mol}}{18.02\ \text{g}} \times \frac{40.8\ \text{kJ}}{\text{mol}}\\ &= 226\ \text{kJ}\end{aligned}$$

The enthalpy change is 226 kJ.

Textbook question 16:

a. **Heating Curve of Ethylene Glycol**



b. $$\begin{aligned}\Delta H_{vap} &= nH_{vap}\\ &= 500\ \text{g} \times \frac{1\ \text{mol}}{62.08\ \text{g}} \times \frac{58.8\ \text{kJ}}{\text{mol}}\\ &= 474\ \text{kJ}\end{aligned}$$

The enthalpy change needed is 474 kJ.

Textbook question 17:

This question involves a sublimation phase change. Water vapour will change to snow directly. However the calculation is done as if there are two phase changes occurring – condensation followed by solidification (freezing). Therefore, the enthalpy value for sublimation would be as follows:

$$H_{sub} = H_{cond} + H_{sol}$$
$$= 40.8\frac{\text{kJ}}{\text{mol}} + 6.03\frac{\text{kJ}}{\text{mol}}$$
$$= 46.83\frac{\text{kJ}}{\text{mol}}$$

$$\Delta H_{fr} = nH_{sub}$$
$$= 1.00\ \text{t} \times \frac{10^6\ \text{g}}{1\ \text{t}} \times \frac{1\ \text{mol}}{18.02\ \text{g}} \times \frac{46.83\ \text{kJ}}{\text{mol}}$$
$$= 2.60 \times 10^6\ \text{kJ (2.60 GJ)}$$

The enthalpy change is 2.6×10^6 kJ.

Textbook question 18:

$$\Delta H_{cond} = nH_{cond}$$
$$= 100\ \text{kg} \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol}}{18.02\ \text{g}} \times \frac{40.8\ \text{kJ}}{1\ \text{mol}}$$
$$= 2.26 \times 10^5\ \text{kJ (226 MJ)}$$

The enthalpy change is 226 MJ.

Textbook question 19:

$$\Delta H_{sol} = nH_{sol}$$
$$= 1.00\ \text{kg} \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol}}{322.24\ \text{g}} \times \frac{78.0\ \text{kJ}}{\text{mol}}$$
$$= 242\ \text{kJ}$$

The enthalpy change is 242 kJ.

Textbook question 20:

The energy released by an exothermic change is absorbed by the surroundings and results in a measurable increase in temperature of the surroundings.

9. The separation that occurs is a result of physical processes.

10. The physical property of boiling points allows the different fractions to be separated.

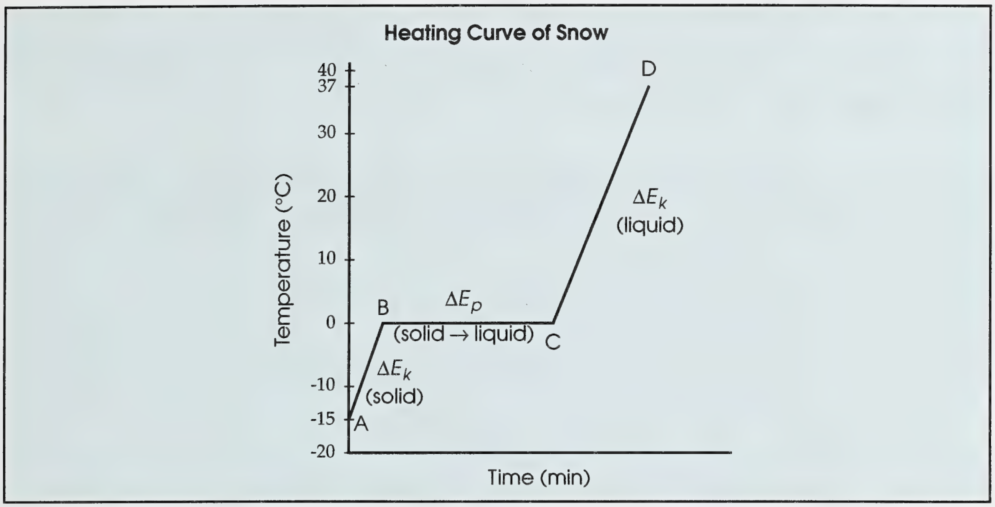
11. As the different fractions move up the column, they cool, which means that the larger fractions with higher boiling points condense in the lower part of the column. The smaller fractions with lower boiling points remain gases longer and are collected higher in the column.

Section 1: Activity 5

1. Potatoes cook faster in a pressure cooker because the water inside boils at a higher temperature (about 115-120°C). The steam that builds up inside the cooker increases the pressure which raises the boiling point of water. The higher temperature results in a faster rate of cooking which means less cooking time.

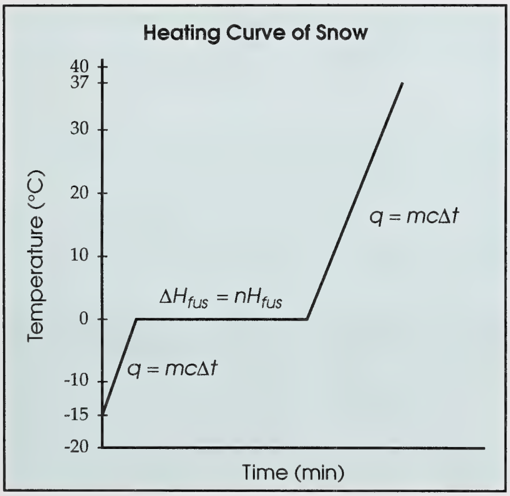
2. **Textbook question 21:**

a.



b. In the first section, A to B, all the energy gained is used to increase the temperature of the system – the average kinetic energy of the molecules increases (ΔE_k). In the second section, B to C, the energy is being used to break bonds between molecules and a phase change occurs (ΔE_p). In the last section, C to D, the incoming energy is once again being used to raise the temperature of liquid water (ΔE_k).

c.



The order of occurrence would be

$q = mc\Delta t$ (solid warming), $\Delta H_{fus} = nH_{fus}$ (melting/fusion), $q = mc\Delta t$ (liquid warming)

d. $$\begin{aligned}\Delta E_{total} &= q + \Delta H_{fus} + q\\ &= mc\Delta t + nH_{fus} + mc\Delta t\\ &= 0.750\ \text{kg} \times \frac{2.01\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times \left(0-(-15)\right)^\circ\text{C} + 750\ \text{g} \times \frac{1\ \text{mol}}{18.02\ \text{g}} \times \frac{6.03\ \text{kJ}}{\text{mol}} + 0.750\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (37-0)^\circ\text{C}\\ &= 390\ \text{kJ}\end{aligned}$$

The total energy needed is 390 kJ.

e. If you eat snow, the heat required to raise its temperature, melt it, and then bring it to body temperature will all have to be provided by the body. This will bring down the core body energy by 390 kJ for every 750 g of snow eaten.

Textbook question 22:

a. $$\begin{aligned}\Delta E_{total} &= \underset{\text{(liquid warming)}}{q} + \underset{\text{(vaporization)}}{\Delta H_{vap}}\\ &= mc\Delta t + nH_{vap}\\ &= 100\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (100-10)^\circ\text{C} + 1.00 \times 10^5\ \text{g} \times \frac{1\ \text{mol}}{18.02\ \text{g}} \times \frac{40.8\ \text{kJ}}{\text{mol}}\\ &= 2.64 \times 10^5\ \text{kJ (264 MJ)}\end{aligned}$$

The total energy needed is 264 MJ.

b. $$\begin{aligned}\Delta E_{total} &= \underset{\text{(liquid warming)}}{q} + \underset{\text{(vaporization)}}{\Delta H_{vap}} + \underset{\text{(vapour warming)}}{q}\\ &= mc\Delta t + n\Delta H_{vap} + mc\Delta t\\ &= 2.7 \times 10^4\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (100-70)^\circ\text{C} + 2.7 \times 10^7\ \text{g} \times \frac{1\ \text{mol}}{18.02\ \text{g}} \times \frac{40.8\ \text{kJ}}{\text{mol}}\\ &\quad + 2.7 \times 10^4\ \text{kg} \times \frac{2.01\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (260-100)^\circ\text{C}\\ &= 7.32 \times 10^7\ \text{kJ (73.2 GJ)}\end{aligned}$$

The total energy needed is 73.2 GJ.

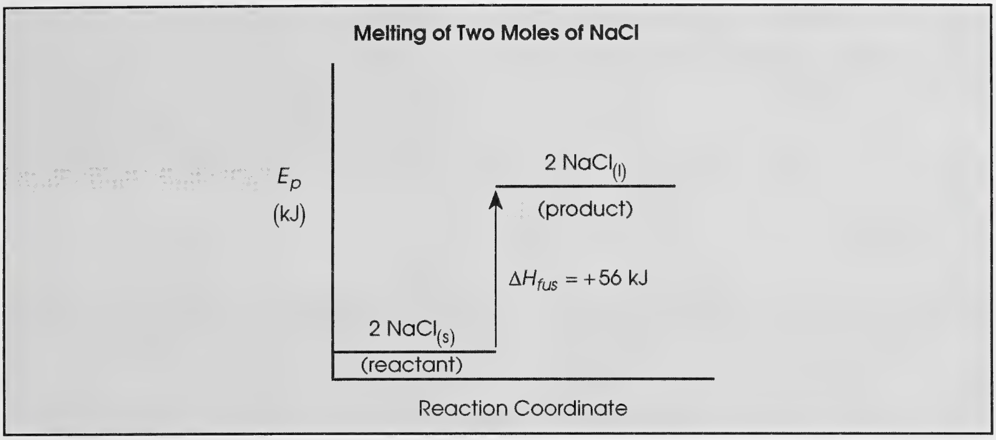
c. The following chart illustrates the advantages and disadvantages of various kinds of electric power generating plants.

Type of Plant	Advantage	Disadvantage
Nuclear power station	It doesn't produce carbon dioxide gas which contributes to global warming.	Any leakage or unsafe disposal of fuel can be a health hazard for all living things.
Solar power station	There are no waste products in its production.	Solar power is expensive to collect and store.
Hydro power station	It uses cheap, renewable energy and is non-polluting.	Rivers have to be dammed. Energy has to be transported.

3. The following answers fill in the blanks in each statement given.

   a. exothermic
   b. chemical system
   c. potential energy
   d. exothermic
   e. endothermic

4.

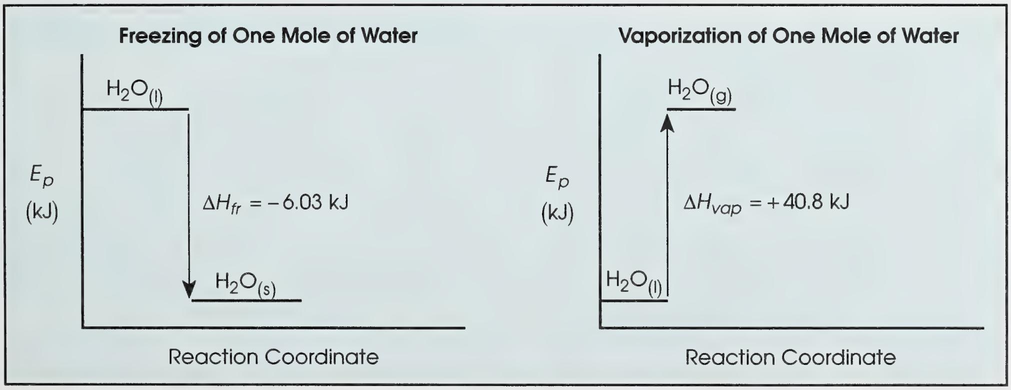


5. **Textbook question 23:**

   a. The molar enthalpy of water freezing is –6.03 kJ/mol.

   b. The molar enthalpy of vaporization of water is +40.8 kJ/mol.

   Textbook question 24:

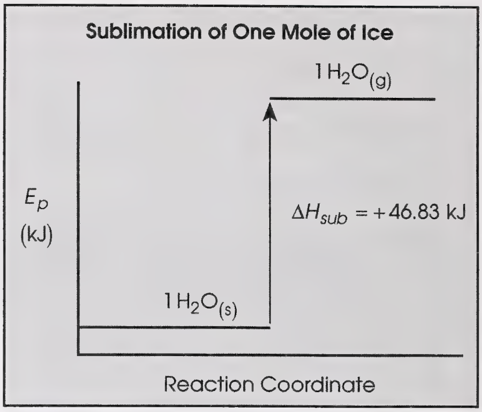


Textbook question 25:

a. The value for sublimation of ice is

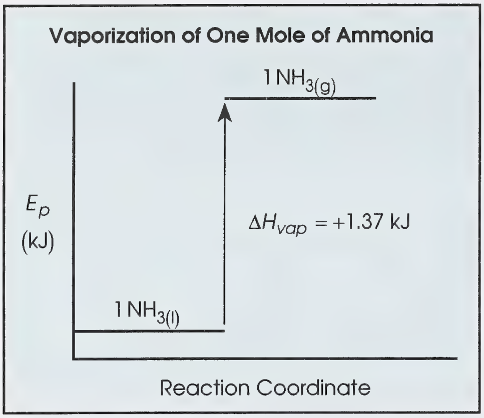
$$\begin{aligned} H_{sub} &= H_{fus} + H_{vap} \\ &= +6.03\ \text{kJ/mol} + (+40.8\ \text{kJ/mol}) \\ &= +46.83\ \text{kJ/mol} \end{aligned}$$

b. The potential energy diagram for the sublimation of ice is shown on the right.

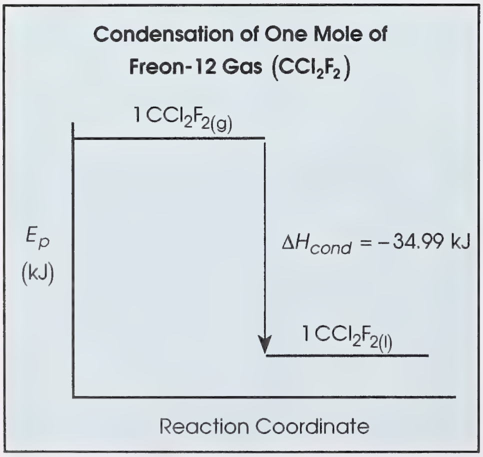


Textbook question 26:

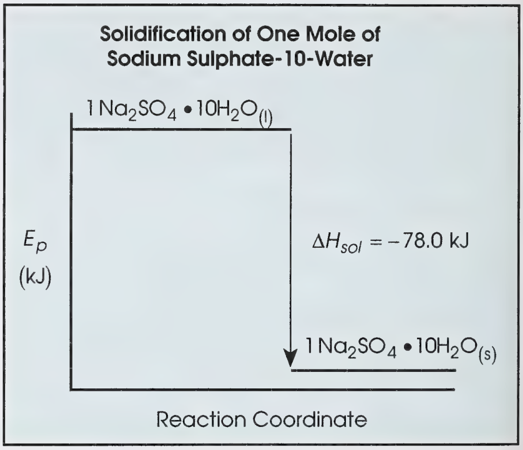
a.



b.



c.



Section 1: Follow-up Activities

Extra Help

1.

Energy Sources	Energy Forms
chemical	heat
nuclear	light
solar	sound
geothermal	electrical

2. Silver would have the greatest increase in temperature because it has the smallest specific heat capacity.

For example, if 10.0 g of each substance absorbed 10.0 J of energy, the following changes in temperature would be observed:

silver

$$\Delta t = \frac{q}{mc} = \frac{10.0\ \text{J}}{10.0\ \text{g} \times 0.237\ \text{J/g} \bullet {}^\circ\text{C}} = \boxed{4.22^\circ\text{C}}$$

benzene

$$\Delta t = \frac{q}{mc} = \frac{10.0\ \text{J}}{10.0\ \text{g} \times 1.74\ \text{J/g} \bullet {}^\circ\text{C}} = 0.575^\circ\text{C}$$

diethyl ether

$$\Delta t = \frac{q}{mc} = \frac{10.0\ \text{J}}{10.0\ \text{g} \times 3.74\ \text{J/g} \bullet {}^\circ\text{C}} = 0.267^\circ\text{C}$$

3.

Phase Change	Exo-/Endothermic	ΔH Sign (+/–)
a. fusion (melting)	endothermic	+
b. solidification (freezing)	exothermic	–
c. condensation	exothermic	–
d. vaporization (boiling)	endothermic	+
e. sublimation	endothermic	+
f. sublimation	exothermic	–

4. a. Section AB (liquid warming) will use the equation $q = mc\Delta t$.
Section BC (liquid vaporizing) will use the equation $\Delta H_{vap} = nH_{vap}$.

b. To find the total energy change of the system, the component energy changes would be added together.

$$\begin{aligned}\Delta E_{total} &= q + \Delta H_{vap} \\ &= mc\Delta t + nH_{vap}\end{aligned}$$

5. $q = mc\Delta t$

$$= 0.0268 \text{ kg} \times \frac{2.01 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times \left(-16.8 - (-32.4)\right)^\circ\text{C}$$

$= 0.840$ kJ The ice cube will absorb 0.840 kJ of heat energy.

6. a. Endothermic changes are shown in B and C.

   Exothermic changes are shown in A and D.

   b. A and D show energy changes with $-\Delta H$ values.

   c. Heat is shown being absorbed in B and C (endothermic changes).

   d. Diagram D shows the greatest ΔH. Diagram C shows the smallest ΔH. (Remember, the sign on the ΔH only refers to heat gained or lost, not how big the ΔH value is.)

   e. For endothermic energy changes, the initial state has less stored energy than the final state.

   For exothermic energy changes, the initial state has more stored energy than the final state.

Enrichment

1. Glauber's salt is $Na_2SO_4 \bullet 10H_2O$. It melts close to room temperature and has a molar heat of fusion of 78 kJ/mol. The high molar heat of fusion implies that Glauber's salt is very efficient in storing heat energy. Solar homes can store heat by letting the sun melt a block of solid $Na_2SO_4 \bullet 10H_2O$. Large quantities of heat can be stored by even a small amount of the solid.

2. There are several approaches to answer this problem. One example is given.

   Investigation: Measuring the Specific Heat Capacity of Water

   Materials

   - a kettle of known power output
   - stop watch
   - balance
   - thermometer

   Procedure

   - Measure the mass of the water in the kettle.
   - Measure the initial temperature of the water.
   - Measure the time required to heat the water to about 80°C.
   - Measure the highest temperature reached by the water.

   Observations

   The following calculations should be done to determine the specific heat capacity.

   - Calculate the energy supplied to the water:

$$\text{energy} = \text{power} \times \text{time}$$

- Calculate the energy needed to heat 1 kg of water:

energy for 1 kg = energy ÷ mass of water in kg

- Calculate the energy needed for 1 kg if the temperature increases only by 1°C.

energy for 1 kg per 1°C = energy for 1 kg ÷ change in temperature

Analysis

Sources of error may include the following:

- The design does not allow for heat lost to surroundings.
- The design does not account for the heat used to warm up the kettle.
- The design assumes the power output of the kettle is correct.

Conclusion

The design has a high source of error. Alternate methods to solve the problem should be considered.

3. The air does not burn the skin because the air has a low specific heat capacity and low density. Energy flows from the hot air to your hands but the energy is spread out over a large surface area minimizing any localized burning. Air has a low thermal conductivity as well. Therefore, heat is transferred from the air to your skin quite slowly. Metal baking sheets have low specific heat capacities as well, but have relatively high densities and good conductivity. Large amounts of heat transfer take place quickly between the baking sheet and your skin to a localized area of touch. Also, the heat lost by the baking sheet in the area you are touching is quickly replaced from other areas of the sheet due to the high thermal conductivity of the metal.

Section 2: Activity 1

1. The heat energy from the hot chocolate was transferred to your mouth.

2. a. physical or chemical system
   b. energy flow
   c. water
   d. insulation
   e. thermometer

3. Water is used in calorimeters because it is cheap, readily available, and has a relatively high specific heat capacity. The high *c* value allows water to absorb a large quantity of energy while staying in the liquid state.

4. The general principle is as follows:

Total heat lost by system = Total heat gained by calorimeter

or vice versa

5. The law of conservation of energy states that the total energy change in a chemical system is equal to the total energy change of the calorimeter surroundings. James Prescott Joule helped develop this law.

6. a. If the change in the system is endothermic, the temperature of the water in the calorimeter will decrease.

   b. If the change is exothermic, the temperature of the water in the calorimeter will increase.

7. The vacuum between the double-wall container acts like an insulating material and prevents the transfer of heat from or to the surroundings. Heat loss is prevented further by silvering the walls and having a lid on the flask. Since there is no exchange of energy and matter between the flask and the surroundings, it behaves like an isolated system.

8. Since the ΔH value is negative, this indicates the system lost heat and the reaction is exothermic. The heat flow is from the system to the water in the calorimeter. The temperature of the calorimeter water increases.

9. The symbol ΔH_s represents the change in enthalpy of the system (LiCl). The symbol q represents the heat energy change of the calorimeter water.

10. a. open system b. isolated system c. closed system

11. a. The dissolving process of LiCl is losing heat; the calorimeter water is gaining heat.

    b. H_s is calculated by using the relationship $nH_s = vc\Delta t$ or $nH_s = mc\Delta t$. It is assumed that the dilute solution of LiCl has the same physical properties of pure water (that is, the same specific heat capacity).

    c. ΔH_s represents enthalpy change and q represents the quantity of heat.

12. **Textbook question 27:**

    The assumptions made in solving calorimeter problems are the following:

    - There is no heat transferred between the calorimeter and the surrounding environment.
    - Heat transfer between the system and the calorimeter itself is neglible.
    - Dilute aqueous solutions have the same density and specific heat capacity as pure water.

    Textbook question 28:

    The measurements that limit the certainty are as follows:

    - the temperature measurement – It limits the certainty of the result to two significant digits if the temperatures used are less than 10°C.

    - the specific heat capacity – It limits the experimental result to three significant digits.

    Textbook question 29:

$$\Delta H_s = q$$
$$nH_s = mc\Delta t$$
$$10\text{ g} \times \frac{1\text{ mol}}{60.07\text{ g}} \times H_s = 0.150\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 3.7^\circ\text{C}$$
$$H_s = 14\text{ kJ/mol}$$

The molar enthalpy of solution is $+14$ kJ/mol (endothermic).

Textbook question 30:

$$
\begin{aligned}
\Delta H_{dil} &= q \\
nH_{dil} &= mc\Delta t \\
0.0431\ \text{L} \times \frac{11.6\ \text{mol}}{1\ \text{L}} \times H_{dil} &= 0.500\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 2.6^\circ\text{C} \\
H_{dil} &= 11\ \text{kJ/mol}
\end{aligned}
$$

The molar enthalpy of dilution is -11 kJ/mol (exothermic).

Textbook question 31:

$$
\begin{aligned}
\Delta H_{fr} &= q \qquad \textbf{(Note: } \Delta H_{fr} \leftarrow \text{freezing)} \\
nH_{fr} &= mc\Delta t \\
10.0\ \text{g} \times \frac{1\ \text{mol}}{69.72\ \text{g}} \times H_{fr} &= 0.050\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (27.8 - 24.0)^\circ\text{C} \\
H_{fr} &= 5.6\ \text{kJ/mol}
\end{aligned}
$$

The molar enthalpy of solidification is -5.6 kJ/mol.

Since you were not given the specific heat capacity of liquid or solid gallium, the assumption is made that the energy transferred by the gallium as a solid is negligible.

13.

$$
\underset{\left(\begin{array}{c}\text{zinc}\\ \text{cooling}\end{array}\right)}{q} = \underset{\left(\begin{array}{c}\text{calorimeter water}\\ \text{warming}\end{array}\right)}{q}
$$

$$
\begin{aligned}
mc\Delta t &= mc\Delta t \\
c &= \frac{mc\Delta t}{m\Delta t} \\
&= \frac{500.0\ \text{g} \times 4.19\ \text{J/g} \bullet {}^\circ\text{C} \times (19.8 - 15.0)^\circ\text{C}}{65.8\ \text{g} \times (410.0 - 19.8)^\circ\text{C}} \\
&= 0.392 \frac{\text{J}}{\text{g} \bullet {}^\circ\text{C}}
\end{aligned}
$$

The specific heat capacity of solid zinc is 0.392 J/g • °C.

Check your units! The answer should end up with the correct units after all cancelled units disappear.

Also, it is important to note that, even though the difference, (19.8 – 15.0)°C, ends up as a number with two significant digits (4.8), this does **NOT** affect the significant digits of the answer. The original measurements are the numbers considered when deciding the significant digits of the answer.

As well, don't get measurements from each side of these energy calculations mixed up. For example, don't mix up the Δt values if they are on each side of the equation.

14. $$\underset{\begin{pmatrix}\text{ice}\\ \text{melting}\end{pmatrix}}{\Delta H} = \underset{\begin{pmatrix}\text{calorimeter}\\ \text{water cooling}\end{pmatrix}}{q}$$

$$2.52\text{ kJ} = mc\Delta t$$

$$\Delta t = \frac{2.52\text{ kJ}}{0.1000\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}}}$$

$$= 6.01^\circ\text{C}$$ The temperature change was 6.01°C.

$$\begin{array}{ccccc}\text{final} & = & \text{initial} & - & \text{temperature}\\ \text{temperature} & & \text{temperature} & & \text{change}\end{array}$$

$$t_f = (25.4 - 6.01)^\circ\text{C}$$
$$= 19.4^\circ\text{C}$$

The final temperature of the entire system was 19.4°C.

Keep all numbers of multistep calculations in your calculator and only round off the final answer.

Section 2: Activity 2

1. The change involved is endothermic. The ΔH value is positive.

2. The chemical equation representing the dissolving of $NaCl_{(s)}$ is

$$NaCl_{(s)} \rightarrow Na^+{}_{(aq)} + Cl^-{}_{(aq)}$$

3. Variables: $v = 100$ mL solution $\quad M_{(NH_4Cl)} = 53.50$ g/mol

$C = 1.00$ mol/L $NH_4Cl_{(aq)}$ $\quad m = ?$

$$m_{(NH_4Cl)} = 0.100\ \cancel{L} \times \frac{1.00\ \cancel{\text{mol } NH_4Cl}}{\cancel{L}} \times \frac{53.50\text{ g}}{1\ \cancel{\text{mol } NH_4Cl}}$$

$$= 5.35\text{ g}$$ The mass of NH_4Cl required is 5.35 g.

4. The following is a list of materials:

- solid ammonium chloride
- weighing paper or boat
- balance
- scoop
- 250 mL beaker (for support as shown in Figure 10.23 on page 303 of *Nelson Chemistry*)
- 100 mL graduated cylinder
- two nested polystyrene cups with lid
- lab apron
- safety glasses
- thermometer

5. An example evidence table for dissolving $NH_4Cl_{(s)}$ may be as follows:

Trial	Initial Temperature (°C)	Final Temperature (°C)	Mass of $NH_4Cl_{(s)}$ (g)
1	24.5	21.1	5.35
2	24.6	21.3	5.35
3	24.3	20.8	5.35

6. Trial 1: $\Delta t = (24.5 - 21.1)°C = 3.4°C$ Trial 2: $\Delta t = (24.6 - 21.3)°C = 3.3°C$ Trial 3: $\Delta t = (24.3 - 20.8)°C = 3.5°C$

$$\text{Average } \Delta t = \frac{(3.4 + 3.3 + 3.5)°C}{3}$$

$= 3.4°C$ The average temperature change is 3.4°C.

7.
$$\underset{\left(\begin{array}{c}NH_4Cl_{(s)}\\ \text{dissolving}\end{array}\right)}{\Delta H_s} = \underset{\left(\begin{array}{c}\text{calorimeter water}\\ \text{cooling}\end{array}\right)}{q}$$

$$nH_s = mc\Delta t$$

$$5.35\text{ g} \times \frac{1\text{ mol}}{53.50\text{ g}} \times H_s = 0.100\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet °C} \times 3.4°C$$

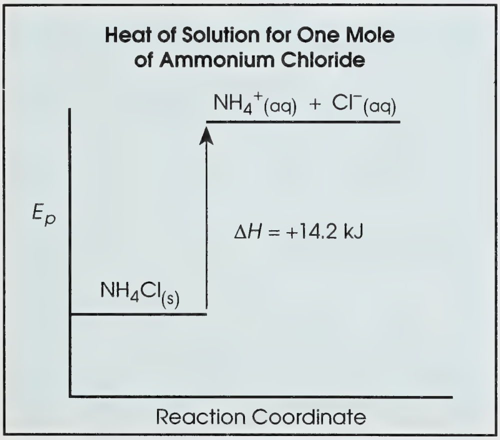
$H_s = 14.2\text{ kJ/mol}$ The molar enthalpy of solution is 14.2 kJ/mol.

The answer has three significant digits because the original temperature measurements had three significant digits.

8. The energy change was endothermic. Operationally, the temperature of the water went down, which means that energy was absorbed by the process.

9. $NH_4Cl_{(s)} \rightarrow NH_4{}^+{}_{(aq)} + Cl^-{}_{(aq)}$

10.



11.
$$\% \text{ difference} = \frac{|\text{experimental value} - \text{predicted value}|}{|\text{predicted value}|} \times 100\%$$

$$= \frac{|14.2\text{ kJ/mol} - 14.8\text{ kJ/mol}|}{|14.8\text{ kJ/mol}|} \times 100\%$$

$= 4.05\%$ The percent difference is 4.05%.

12. The value of ΔH_s is directly related to the amount of substance. Therefore, if you dissolved two times the amount of solute, you would get two times the amount of energy change. The value of H_s would not change because H_s is already based on one mole of solute. If you divide two times the amount of heat by two times the amount of substance, you get the original H_s.

13. The mass of ammonium nitrate (NH_4NO_3) required may be determined as follows:

Step 1 Calculate the moles of ammonium nitrate using calorimetry principles.

$$\underset{\begin{pmatrix}NH_4NO_3\\ \text{dissolving}\end{pmatrix}}{\Delta H_s} = \underset{\begin{pmatrix}\text{calorimeter}\\ \text{water cooling}\end{pmatrix}}{q}$$

$$nH_s = mc\Delta t$$

$$n = \frac{mc\Delta t}{H_s}$$

$$= \frac{0.250 \text{ kg} \times \dfrac{4.19 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 5.0^\circ\text{C}}{25 \text{ kJ/mol}}$$

$$= 0.2095 \text{ mol}$$

Step 2 Convert moles to mass. (Keep all those digits in your calculator!)

$$m_{(NH_4NO_3)} = 0.2095 \text{ mol} \times \frac{80.06 \text{ g}}{1 \text{ mol}}$$

$= 17$ g The mass of ammonium nitrate needed is 17 g.

Remember that intermediate step answers may be rounded in this course for illustration purposes. The final answers are calculated using unrounded intermediate answers.

14. a. Heat is lost by the calorimeter water and it is gained by the ice.

b. Heat lost (ΔE_{loss}) by the calorimeter water may be calculated as follows:

$$\Delta E_{loss} = \underset{(\text{water cooling})}{q}$$

$$\Delta E_{loss} = mc\Delta t$$

$$= 0.09950 \text{ kg} \times \frac{4.19 \text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (32.4 - 15.6)^\circ\text{C}$$

$$= 7.004 \text{ kJ}$$

$= 7.00$ kJ The heat lost by the original water in the calorimeter is 7.00 kJ.

c. The total heat gained $\left(\Delta E_{gain}\right)$ by the ice and ice water may be calculated as follows:

$$\begin{aligned}
\Delta E_{gain} &= \underset{\text{(ice melting)}}{\Delta H_{fus}} + \underset{\text{(ice water warming)}}{q} \\
&= nH_{fus} + mc\Delta t \\
&= 17.33\ \text{g} \times \frac{1\ \text{mol}}{18.02\ \text{g}} \times H_{fus} + 0.01733\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^{\circ}\text{C}} \times (15.6 - 0.0)^{\circ}\text{C} \\
&= 0.96171\ \text{mol} \times H_{fus} + 1.1328\ \text{kJ}
\end{aligned}$$

Calculating as far as possible, the total heat gained is $0.962\ \text{mol} \times H_{fus} + 1.13\ \text{kJ}$.

d. Since $\Delta E_{loss} = \Delta E_{gain}$,

$$\begin{aligned}
7.004\ \text{kJ} &= 0.96171\ \text{mol} \times H_{fus} + 1.1328\ \text{kJ} \\
5.8712\ \text{kJ} &= 0.96171\ \text{mol} \times H_{fus} \\
H_{fus} &= \frac{5.8712\ \text{kJ}}{0.96171\ \text{mol}} \\
&= 6.11\ \frac{\text{kJ}}{\text{mol}}
\end{aligned}$$

The molar enthalpy of fusion of ice is +6.11 kJ/mol.

(Remember, the + sign is attached to show an endothermic process.)

15.
$$\begin{aligned}
\underset{\text{(reaction)}}{\Delta H_r} &= \underset{\text{(water warming)}}{q} \\
8.05\ \text{kJ} &= mc\Delta t \\
8.05\ \text{kJ} &= m \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^{\circ}\text{C}} \times (25.0 - 20.0)^{\circ}\text{C} \\
m &= 0.384\ \text{kg}
\end{aligned}$$

The mass of water in the calorimeter is 0.384 kg (384 g).

16.
$$\begin{aligned}
\underset{\text{(reaction)}}{\Delta H_s} &= \underset{\text{(water warming)}}{q} \\
nH_s &= mc\Delta t \\
8.50\ \text{g} \times \frac{1\ \text{mol NaNO}_3}{85.00\ \text{g}} \times H_s &= 0.1000\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^{\circ}\text{C}} \times 5.2^{\circ}\text{C} \\
H_s &= 22\ \text{kJ/mol}
\end{aligned}$$

The molar heat of solution of sodium nitrate is $+22\ \text{kJ/mol}$.

17.

$$\begin{array}{ccc} \Delta E_{loss} & = & \Delta E_{gain} \\ \text{(copper)} & & \text{(calorimeter water)} \\ q & = & q \\ \begin{pmatrix}\text{copper}\\ \text{cooling}\end{pmatrix} & & \begin{pmatrix}\text{water}\\ \text{warming}\end{pmatrix} \end{array}$$

$$mc\Delta t = mc\Delta t$$

$$70.0\text{ g} \times \frac{0.385\text{ J}}{\text{g} \bullet {}^\circ\text{C}} \times \left(95.2^\circ\text{C} - t_f\right) = 101\text{ g} \times \frac{4.19\text{ J}}{\text{g} \bullet {}^\circ\text{C}} \times \left(t_f - 22.5^\circ\text{C}\right)$$

$$2565.6\text{ J} - 26.95\frac{\text{J}}{{}^\circ\text{C}}\left(t_f\right) = 423.19\frac{\text{J}}{{}^\circ\text{C}}\left(t_f\right) - 9521.8\text{ J}$$

$$450.14\frac{\text{J}}{{}^\circ\text{C}}\left(t_f\right) = 12087.4\text{ J}$$

$t_f = 26.9^\circ\text{C}$ The final temperature of the system will be 26.9°C.

Note:

- The symbol t_f represents the final temperature.
- The temperature change on both sides is set up so that the value is positive.

18.

$$\begin{array}{ccc} \Delta H_s & = & q \\ \text{(dissolving)} & & \text{(water cooling)} \end{array}$$

$$nH_s = mc\Delta t$$

$$0.1000\text{ L} \times \frac{1.0\text{ mol}}{\text{L}} \times \frac{34.8\text{ kJ}}{\text{mol}} = 0.100\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times \Delta t$$

$\Delta t = 8.3^\circ\text{C}$ The temperature change that occurred was 8.3°C.

Note: The moles of potassium nitrate in this case were found by multiplying the concentration times the volume ($n = Cv$).

19.

$$\begin{array}{ccccc} & & \Delta E_{loss} & = & \Delta E_{gain} \\ & & \text{(steam)} & & \text{(calorimeter water)} \\ \Delta H_{cond} & + & q & = & q \\ \begin{pmatrix}\text{steam}\\ \text{condensing}\end{pmatrix} & & \begin{pmatrix}\text{water}\\ \text{cooling}\end{pmatrix} & & \begin{pmatrix}\text{calorimeter}\\ \text{water warming}\end{pmatrix} \end{array}$$

$$nH_{cond} + mc\Delta t = mc\Delta t$$

$$\left(20.0\text{ g} \times \frac{1\text{ mol}}{18.02\text{ g}} \times \frac{40.8\text{ kJ}}{\text{mol}}\right) + \left(0.0200\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (100.0 - 39.9)^\circ\text{C}\right) = m \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (39.9 - 20.2)^\circ\text{C}$$

$$45.283\text{ kJ} + 5.0364\text{ kJ} = m \times \frac{82.543\text{ kJ}}{\text{kg}}$$

$$m = \frac{50.319\text{ kJ}}{82.543\text{ kJ/kg}}$$

$$= 0.610\text{ kg } (610\text{ g})$$

The mass of the calorimeter water was 0.610 kg or 610 g.

20. The energy released by the burning candle is found by using the first water data given where the mass of water is 50 g and the temperature changes from 20°C to 26°C.

$$\underset{\left(\begin{matrix}\text{candle}\\ \text{burning}\end{matrix}\right)}{\Delta H_{comb}} = \underset{\left(\begin{matrix}\text{calorimeter}\\ \text{water warming}\end{matrix}\right)}{q}$$

$$\begin{aligned}\Delta H_c &= mc\Delta t\\ &= 0.050\text{ kg}\times\frac{4.19\text{ kJ}}{\text{kg}\bullet{}^\circ\text{C}}\times(26-20)^\circ\text{C}\\ &= 1.257\text{ kJ}\end{aligned}$$

Since an identical candle is used the second time, the energy released is the same. Therefore,

$$\begin{aligned}\Delta H_c &= q\\ 1.257\text{ kJ} &= mc\Delta t\\ 1.257\text{ kJ} &= 0.150\text{ kg}\times\frac{4.19\text{ kJ}}{\text{kg}\bullet{}^\circ\text{C}}\times\Delta t\\ \Delta t &= \frac{1.257\text{ kJ}}{0.6285\text{ kJ}/^\circ\text{C}}\\ &= 2.0^\circ\text{C}\end{aligned}$$

$$\begin{aligned}t_f &= \Delta t + t_i\\ &= (2.0+20.0)^\circ\text{C}\\ &= 22^\circ\text{C}\end{aligned}$$

The expected final temperature would be 22°C. Since the original measurements had two significant digits, the final answer has two as well.

Section 2: Activity 3

1. Cold water should be used to get acid off the hands. This is the safest way to avoid any reactions which may further damage your skin.

2. a. The balanced equation is

$$H_2SO_{4(aq)} + 2\ NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2\ H_2O_{(l)}$$

b. $$v_{(H_2SO_4)} = 50\text{ m}\cancel{\text{L}}\times\frac{1.0\ \cancel{\text{mol NaOH}}}{\cancel{\text{L}}}\times\frac{1\ \cancel{\text{mol }H_2SO_4}}{2\ \cancel{\text{mol NaOH}}}\times\frac{1\text{ L}}{1.0\ \cancel{\text{mol }H_2SO_4}}$$

$= 25$ mL The minimum volume of sulphuric acid needed is 25 mL.

3. Excess sulphuric acid is added to a sodium hydroxide solution in a calorimeter to ensure a complete reaction. Temperature data are collected through several trials.

4. The materials needed per trial are as follows:

- 50 mL of 1.0 mol/L $NaOH_{(aq)}$
- calorimeter
- (2) 250 mL beakers
- 100 mL graduated cylinder
- thermometer
- 50 mL of 1.0 mol/L $H_2SO_{4(aq)}$
- 2 medicine droppers
- wash bottle
- safety glasses
- lab apron

5. The procedure that can be used is as follows:

- Measure 50 mL of sulphuric acid in a graduated cylinder. Pour it into the calorimeter.
- Measure 50 mL of sodium hydroxide solution.
- Measure the initial temperature of each solution. **Note:** To avoid averaging initial temperatures, you can let all solutions come to room temperature before proceeding.)
- Pour the NaOH solution into the calorimeter and quickly cover with a lid. Note the final maximum or minimum temperature reached by the solution.
- Discard the solution as directed and rinse and dry the calorimeter.
- Repeat the procedure two more times.

6. A sample evidence table is given here:

Data	Trial 1	Trial 2	Trial 3
volume of 1.0 mol/L $NaOH_{(aq)}$	50.0 mL	50.0 mL	50.0 mL
volume of 1.0 mol/L $H_2SO_{4(aq)}$	50.0 mL	50.0 mL	50.0 mL
initial temperature of $H_2SO_{4(aq)}$ (°C)	24.0°C	24.0°C	24.0°C
initial temperature of $NaOH_{(aq)}$ (°C)	24.4°C	24.4°C	24.4°C
final temperature of the mixture (°C)	31.3°C	31.0°C	31.4°C

7. Refer to the answer for question 6, Section 2: Activity 3.

8. a. The initial temperature of the combined solution cannot be measured because of the immediate reaction that occurs.

Since each solution contributed an equal amount to the final solution volume, the initial temperature could be found by simple averaging.

$$t_i(\text{average}) = \frac{(24.0 + 24.4)°\text{C}}{2} = 24.2°\text{C}$$

Note: If each solution had contributed unequal amounts, the initial temperature would have been a proportional average.

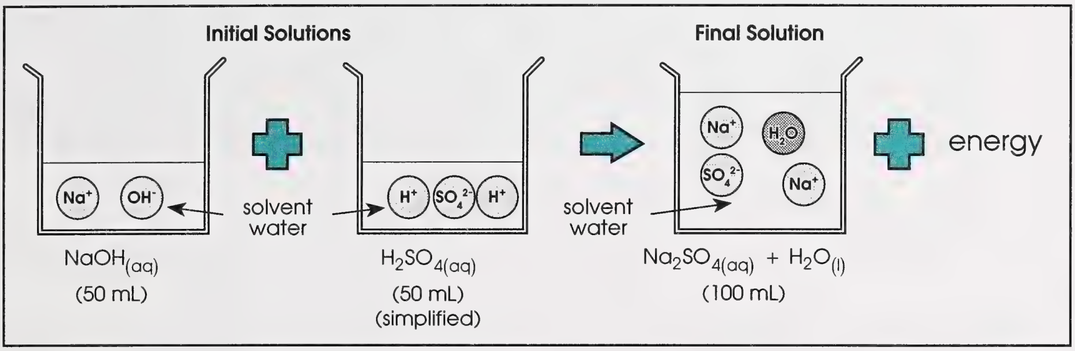
The final temperature can be averaged as well.

$$t_f(\text{average}) = \frac{(31.3 + 31.0 + 31.4)°\text{C}}{3}$$
$$= 31.2°\text{C}$$

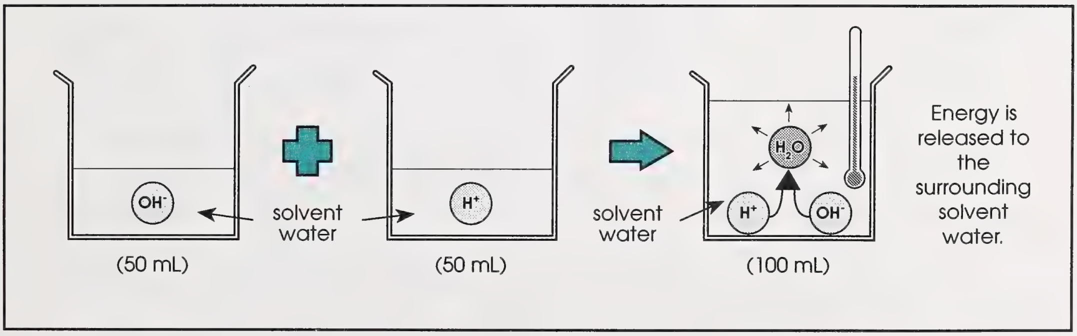
The average temperature change, then, is as follows.

$$\begin{aligned}\Delta t(\text{average}) &= t_f(\text{average}) - t_i(\text{average})\\ &= (31.2 - 24.2)^\circ\text{C}\\ &= 7.0^\circ\text{C}\end{aligned}$$

b. The following explanation is a simplified version of what occurs in the solution when $NaOH_{(aq)}$ and $H_2SO_{4(aq)}$ are mixed. It is given as a means to understanding the energy transfers involved.



When the initial solutions are mixed, the energy changes observed (increase in temperature) come from the $H^+{}_{(aq)}$ and $OH^-{}_{(aq)}$ ions combining to form $H_2O_{(l)}$. Neither the other ions nor the solvent water create the energy change. However, the solvent water does absorb the energy from the chemical change and thus it increases in temperature.



Therefore, when assigning values to your variables, the solvent water and its volume are placed on the calorimeter side (ΔE_{gain}) of your heat equation $(\Delta E_{loss} = \Delta E_{gain})$ and the reaction and its components are placed on the other side (ΔE_{loss}) of your equation.

ΔE_{loss} = (reaction)	ΔE_{gain} (calorimeter water) (solvent)
ΔE_{loss} represents an enthalpy change and is equal to nH_r where r stands for *reaction*. The H_r is the unknown value (the molar enthalpy of neutralization or reaction) for which you are solving. Therefore, you need a value for n dealing with the reaction. Since both NaOH and H_2SO_4 are involved in the reaction, but only NaOH is completely reacted, the volume and concentration for $NaOH_{(aq)}$ give you the value of n required.	ΔE_{gain} represents a heat gain by the solvent or calorimeter water and is solved by $mc\Delta t$. The variables are as follows: m = 100 g or 0.100 kg (the volume of the combined solutions) $c = \frac{4.19\ \text{J}}{\text{g}\bullet{}^\circ\text{C}}$ or $\frac{4.19\ \text{kJ}}{\text{kg}\bullet{}^\circ\text{C}}$ (The assumption made is that the solution has the same c value as water.) Δt = the observed change in temperature

So, the solution for the molar enthalpy of neutralization (H_r) is as follows:

$$\begin{aligned}
\Delta E_{loss} &= \Delta E_{gain} \\
\text{(neutralization)} &\quad \text{(solvent water)} \\
\Delta H_r &= q \\
nH_r &= mc\Delta t \\
0.050\ \text{L} \times \frac{1.0\ \text{mol NaOH}}{\text{L}} \times H_r &= 0.100\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg}\bullet{}^\circ\text{C}} \times 7.0^\circ\text{C} \\
H_r &= \frac{2.933\ \text{kJ}}{0.050\ \text{mol}} \\
&= 59\ \frac{\text{kJ}}{\text{mol}}
\end{aligned}$$

The molar enthalpy of neutralization for $NaOH_{(aq)}$ is $-59\frac{\text{kJ}}{\text{mol}}$ since energy was released.

9. The percent error can be calculated as follows:

$$\begin{aligned}
\%\ \text{error} &= \frac{\left|\text{experimental value} - \text{accepted value}\right|}{\left|\text{accepted value}\right|} \times 100\% \\
&= \frac{\left|-59\ \text{kJ/mol} - (-57\ \text{kJ/mol})\right|}{\left|-57\ \text{kJ/mol}\right|} \times 100\% \\
&= 3.5\%
\end{aligned}$$

Since the percent error is within acceptable limits, the error can be attributed to normal experimental errors and the experimental design is judged to be acceptable.

10. **Textbook question 32:**

a.
$$
\begin{aligned}
q &= mc\Delta t \\
&= 0.100\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 5.0^\circ\text{C} \\
&= 2.095\ \text{kJ} \\
&= 2.1\ \text{kJ} \quad \text{The energy change of the water is 2.1 kJ.}
\end{aligned}
$$

b.
$$
\begin{aligned}
\Delta E_{total} &= q_{water} + q_{cups} + q_{stirrer} + q_{thermometer} \\
&= 2.095\ \text{kJ} + 0.00537\ \text{kJ} + 0.03969\ \text{kJ} + 0.03336\ \text{kJ} \\
&= 2.173\ \text{kJ} \\
&= 2.2\ \text{kJ} \quad \text{The total energy change is 2.2 kJ.}
\end{aligned}
$$

c.
$$
\begin{aligned}
\%\ \text{error} &= \frac{|\,2.173\ \text{kJ} - 2.095\ \text{kJ}\,|}{|\,2.173\ \text{kJ}\,|} \times 100\% \\
&= 3.6\% \quad \text{Using only the energy change of the water, the percent error is 3.6\%.}
\end{aligned}
$$

d. Since the percent error has a small value and is probably smaller than experiment errors, the assumption is acceptable.

11. Based on the concepts learned about energy and calorimetry so far, an insulated metal can would likely be the easiest calorimeter to make and it would give the best results.

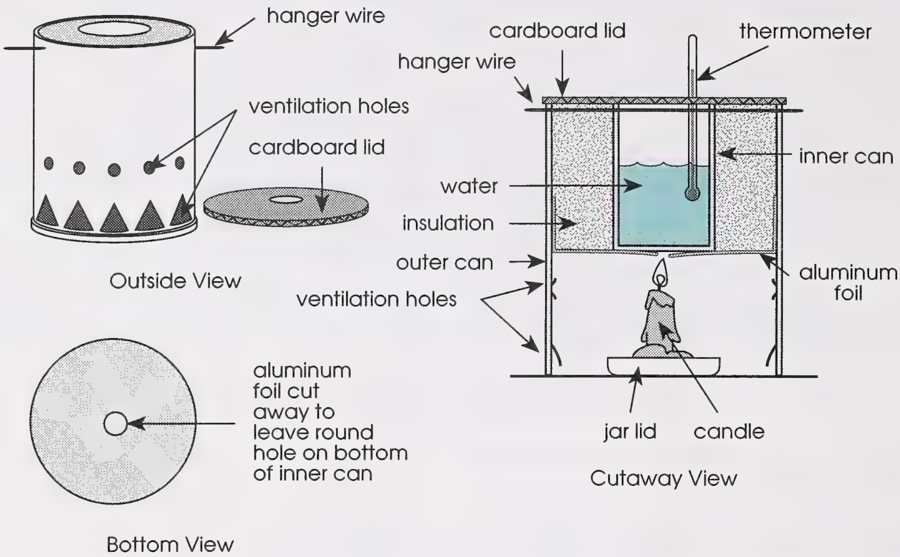
12. A list of materials is as follows:

- metal can calorimeter
  - small tin can (280 mL soup can – one end removed)
  - large tin can (1.4 L juice can – both ends removed)
  - aluminum foil
  - fibreglass insulation or mineral wool
  - clothes hanger wire
  - cardboard or polystyrene for lid
- paraffin candle
- 100 mL graduated cylinder
- thermometer
- jam jar lids
- can-opener or tin snips
- matches
- balance
- large nail

Notes on the calorimeter:

- The hanger wire goes through the two holes near the open end of the inner can, allowing it to be suspended in the outer can.
- Ventilation holes are required around the bottom and around the middle of the large can, just below the level of the inner can's bottom.
- Ventilation holes can be made with a can-opener or a nail.
- The aluminum foil is wrapped up around the bottom of the inner can and the insulation; then the setup is suspended in the outer can.
- The hole is cut in the aluminum foil so the candle flame has direct contact with the inner can.
- The thermometer hole in the lid can be made slightly off-centre so that the thermometer does not hit the hanger wire.

Combustion Reaction Calorimeter



13. The steps for the procedure are as follows:

- Light the candle and drip some wax into a jam jar lid. Stand the candle in the wax.
- Measure and record the mass of the candle with the jar lid.
- Set up the apparatus as shown in the preceding diagrams.
- Adjust the height of the candle or the calorimeter by using extra jam jar lids – the flame tip should just touch the bottom of the inner can.
- Carefully measure 100 mL of cold tap water and pour the water into the calorimeter.
- Record the initial temperature of the water.
- Light the candle and quickly position the calorimeter on top of the flame.
- Heat the water until its temperature is about 35°C; then blow out the candle.
- Stir the water until the highest temperature is reached and record this temperature.
- Measure the mass of the candle (along with any drippings from the candle) and the lid again.
- Repeat the experiment two times.
- The flame size can be made smaller if necessary by cutting the wick.

14. An evidence table with sample data is given here:

Data	Trial 1	Trial 2	Trial 3
initial mass of candle + lid (g)	48.41	47.80	47.29
final mass of candle + lid (g)	47.90	47.39	46.71
initial temperature of water (°C)	15.0	14.5	15.0
final temperature of water (°C)	39.0	38.0	38.5
volume of water used (mL)	100.0	100.0	100.0

15. a. The balanced equation for the complete combustion of paraffin wax is as follows:

$$C_{25}H_{52(s)} + 38\,O_{2(g)} \rightarrow 25\,CO_{2(g)} + 26\,H_2O_{(g)}$$

b. The reaction is exothermic because the temperature of the calorimeter water increased.

16. The complete calculations are shown for Trial 1 only; the same method can be used for Trials 2 and 3.

Calculations	Trial 1	Trial 2	Trial 3
mass of candle burned (g)	48.41 − 47.90 = 0.51	47.80 − 47.39 = 0.41	47.29 − 46.71 = 0.58
temperature change of water (°C)	39.0 − 15.0 = 24.0	38.0 − 14.5 = 23.5	38.5 − 15.0 = 23.5

Trial 1:

$$\Delta E_{loss} = \Delta E_{gain}$$

$$\begin{pmatrix}\text{paraffin}\\ \text{combustion}\end{pmatrix} \quad \begin{pmatrix}\text{calorimeter water}\\ \text{warming}\end{pmatrix}$$

$$\Delta H_c = q$$

$$nH_c = mc\Delta t$$

$$0.51\text{ g} \times \frac{1\text{ mol}}{352.77\text{ g}} \times H_c = 0.1000\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (39.0 - 15.0)^\circ\text{C}$$

$$H_c = \frac{10.056\text{ kJ}}{0.001446\text{ mol}}$$

$$= 7.0 \times 10^3\ \frac{\text{kJ}}{\text{mol}}$$

$$= 7.0\ \frac{\text{MJ}}{\text{mol}}$$

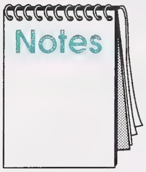
The molar heat of combustion for paraffin wax is – 7.0 MJ/mol since heat was released.

Value for Trial 2: The molar heat is – 8.5 MJ/mol.
Value for Trial 3: The molar heat is – 6.0 MJ/mol.

17. The design of the calorimeter seemed adequate to determine the molar heat of combustion for paraffin wax. The greatest temperature changes were achieved during Trial 1 and Trial 2. In Trial 1, the position of the flame relative to the calorimeter was such that the tip of the flame just touched the can. Trial 2 should have given a lower value but heat loss must have been very low due to insulating the calorimeter with mineral wool. Heat was lost to the surroundings and to the bottom of the outer metal can creating a major source of error.

18.
$$\begin{aligned}
\Delta E_{loss} &= \Delta E_{gain} \\
\Delta H_c &= q \\
nH_c &= mc\Delta t \\
0.136\ \text{g} \times \frac{1\ \text{mol}}{24.31\ \text{g}} \times H_c &= 0.300\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 1.13^\circ\text{C} \\
H_c &= \frac{1.4204\ \text{kJ}}{0.0055944\ \text{mol}} \\
&= 254\ \frac{\text{kJ}}{\text{mol}}
\end{aligned}$$

The molar enthalpy of combustion of magnesium is –254 kJ/mol.

19. 

Remember, the initial temperature of the mixture cannot be measured, so it must be calculated. Since the $HCl_{(aq)}$ volume is two times the $NaOH_{(aq)}$ volume, the $HCl_{(aq)}$ solution contributes twice as much to the initial temperature. Therefore, the initial temperature of the mixture would be calculated as follows:

$$(24.0^\circ\text{C})\frac{2}{3} + (22.0^\circ\text{C})\frac{1}{3} = 23.3^\circ\text{C}$$

Also, since both solutions contribute to the solvent water (considered as the calorimeter water), the volume of calorimeter water used is 75.0 mL (50.0 mL + 25.0 mL).

$$\begin{aligned}
\underset{\text{(neutralization)}}{\Delta H_n} &= \underset{\begin{pmatrix}\text{solvent water}\\ \text{warming}\end{pmatrix}}{q} \\
nH_n &= mc\Delta t \\
0.0250\ \text{L} \times \frac{1.0\ \text{mol}}{\text{L}} \times H_n &= 0.0750\ \text{kg} \times \frac{4.19\ \text{kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times (32.3 - 23.3)^\circ\text{C} \\
H_n &= \frac{2.828\ \text{kJ}}{0.025\ \text{mol}} \\
&= 1.1 \times 10^2\ \frac{\text{kJ}}{\text{mol}}
\end{aligned}$$

The molar heat of neutralization for $NaOH_{(aq)}$ is -1.1×10^2 kJ/mol.

20.
$$\underset{\begin{pmatrix}\text{ethane}\\ \text{combustion}\end{pmatrix}}{\Delta H_c} = \underset{\begin{pmatrix}\text{calorimeter water}\\ \text{warming}\end{pmatrix}}{q}$$

$$nH_c = mc\Delta t$$

$$m \times \frac{1\text{ mol}}{30.08\text{ g}} \times \frac{1428\text{ kJ}}{\text{mol}} = 0.800\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg}\bullet{}^\circ\text{C}} \times (90.0 - 25.0)^\circ\text{C}$$

$$m = \frac{217.88\text{ kJ} \times 30.08\text{ g}}{1428\text{ kJ}}$$

$$= 4.59\text{ g}$$

The mass of ethane that needs to be burned is 4.59 g.

Even though the molar heat value was given as –1428 kJ/mol, the negative sign does not go in the calculation. Remember, the signs associated with molar heat values merely tell you whether heat is lost or gained.

Section 2: Activity 4

1. The banana split would contain 955 calories. The hamburger would contain 239 calories.

banana split

$$4 \times 10^6\text{ J} \times \frac{1\text{ kJ}}{1000\text{ J}} \times \frac{1\text{ calorie}}{4.19\text{ kJ}} = 955\text{ calories}$$

hamburger

$$1 \times 10^6\text{ J} \times \frac{1\text{ kJ}}{1000\text{ J}} \times \frac{1\text{ calorie}}{4.19\text{ kJ}} = 239\text{ calories}$$

2. Answers will vary. Four substances are peanuts, cookies, gasoline, and potato chips. The answers could include anything that would give a vigourous reaction, requiring an enclosed container.

3. a. bomb calorimeter, simple calorimeter

   b. total, components

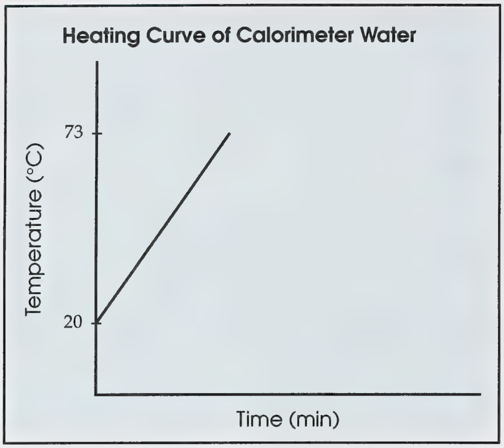
   c. ΔE_{total}

   d. heat capacity

   e. C

4. a. The kinetic energy of the water will increase since it shows an increase in temperature. The potential energy of the bonds in the sugar molecules will decrease because combustion is an exothermic reaction.

b.



c. The relationship used to determine enthalpy change is

$$\underset{\text{(combustion)}}{\Delta H_c} = \underset{\text{(calorimeter)}}{q}$$

$$nH_c = C\Delta t$$

5. **Textbook question 33:**

(Acetylene is ethyne, C_2H_2)

$$\underset{\text{(combustion)}}{\Delta H_c} = \underset{\text{(calorimeter)}}{q}$$

$$nH_c = C\Delta t$$

$$1.12\ \text{g} \times \frac{1\ \text{mol}}{26.04\ \text{g}} \times H_c = \frac{6.49\ \text{kJ}}{°\text{C}} \times 8.55°\text{C}$$

$$H_c = \frac{55.490\ \text{kJ}}{0.043011\ \text{mol}}$$

$$= 1.29 \times 10^3\ \frac{\text{kJ}}{\text{mol}}$$

$$= 1.29\ \frac{\text{MJ}}{\text{mol}}$$

The molar enthalpy of combustion for acetylene is –1.29 MJ/mol.

Textbook question 34:

$$\underset{\text{(hydration)}}{\Delta H_h} = \underset{\text{(calorimeter)}}{q}$$

$$\Delta H_h = C\Delta t$$

$$= \frac{157\ \text{kJ}}{°\text{C}} \times (73 - 27)°\text{C}$$

$$= 7.2 \times 10^3\ \text{kJ}$$

$$= 7.2\ \text{MJ}$$

The enthalpy change of hydration is –7.2 MJ.

Textbook question 35:

Some other factors involved in evaluating alternative fuels include cost, environmental hazards, availability of the fuel, storage, safety, fuel economy, etc.

6. The analysis for Exercise 10 D is as follows:

$$\underset{\text{(combustion)}}{\Delta H_c} = \underset{\text{(calorimeter)}}{q}$$

$$nH_c = C\Delta t$$

$$1.14\ \text{g} \times \frac{1\ \text{mol}}{284.54\ \text{g}} \times H_c = \frac{8.57\ \text{kJ}}{°\text{C}} \times (30.28 - 25.00)°\text{C}$$

$$H_c = \frac{45.250\ \text{kJ}}{0.0040065\ \text{mol}}$$

$$= 1.13 \times 10^4\ \text{kJ/mol}$$

$$= 11.3\ \text{MJ/mol}$$

The molar enthalpy of combustion for stearic acid (fat) is –11.3 MJ/mol.

The molar enthalpy of combustion for sucrose was given as –5.63 MJ/mol.

7. The experimental design seems to be adequate since the molar enthalpy value for stearic acid was found and the problem was answered. However, the combustion of fats and sugars outside the body and their metabolism inside the body may be different.

8. a. Combustion of glucose in the body: $C_6H_{12}O_{6(s)} + 6\,O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)}$

Combustion of methane in machines: $CH_{4(g)} + 2\,O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$

b.

Similarities	Differences
• Both reactions produce carbon dioxide and water vapour as products. • Both reactions are exothermic. • Both reactions have two reactants and two products. • Both reactions involve substances containing carbon, hydrogen, and oxygen.	• Glucose is reacted slowly in your body without flames, whereas methane burns quickly with a blue flame. • The water produced from the glucose reaction in your body is liquid in state, whereas the water produced from the methane combustion is gaseous. • Glucose is a carbohydrate (contains C, H, and O), whereas methane is a hydrocarbon (contains C and H only). • Glucose metabolism in your body occurs with the aid of enzymes, whereas methane combustion occurs on its own (once it is started).

Section 2: Follow-up Activities

Extra Help

1.

System Description	CALORIMETER Temperature Increases	Temperature Decreases
ice at 0°C changes to water at 10°C		✔
sodium hydroxide solution reacts with sulphuric acid	✔	
peanut burns in a bomb calorimeter	✔	
steam at 100°C changes to water at 90.0°C	✔	

2. The assumptions are as follows:

- The polystyrene calorimeter does not absorb heat.
- There is no heat lost to the surroundings.
- The density difference of any aqueous solution in the calorimeter compared to that of water is minimal.

3. a. The mathematical equation used is as follows:

$$\underset{\begin{pmatrix}\text{NaOH}\\\text{dissolving}\end{pmatrix}}{\Delta H_s} = \underset{\begin{pmatrix}\text{solvent water}\\\text{warming}\end{pmatrix}}{q}$$
$$nH_s = mc\Delta t$$

b. The molar heat of solution for $NaOH_{(s)}$ can be calculated as follows:

$$2.0\text{ g} \times \frac{1\text{ mol}}{40.00\text{ g}} \times H_s = 0.100\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 6.0^\circ\text{C}$$
$$H_s = \frac{2.514\text{ kJ}}{0.050\text{ mol}}$$
$$= 50\text{ kJ/mol}$$

The molar heat of solution for $NaOH_{(s)}$ is –50 kJ/mol.

4. The correct order of the statements is **c**, **d**, **a**, **b**.

5.

Variable	Units
ΔE_{total}	kJ, J
c	kJ/kg•°C, J/g•°C
H	kJ/mol, J/mol
ΔH	kJ, J
q	kJ, J
C	kJ/°C, J/°C

6.

$$\underset{\text{(combustion)}}{\Delta H_c} = \underset{\text{(calorimeter)}}{q}$$

$$nH_c = mc\Delta t$$

$$0.285\text{ mol} \times \frac{810.4\text{ kJ}}{\text{mol}} = 8.60\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times \Delta t$$

$$\Delta t = \frac{230.964\text{ kJ}}{36.034\text{ kJ}/{}^\circ\text{C}}$$

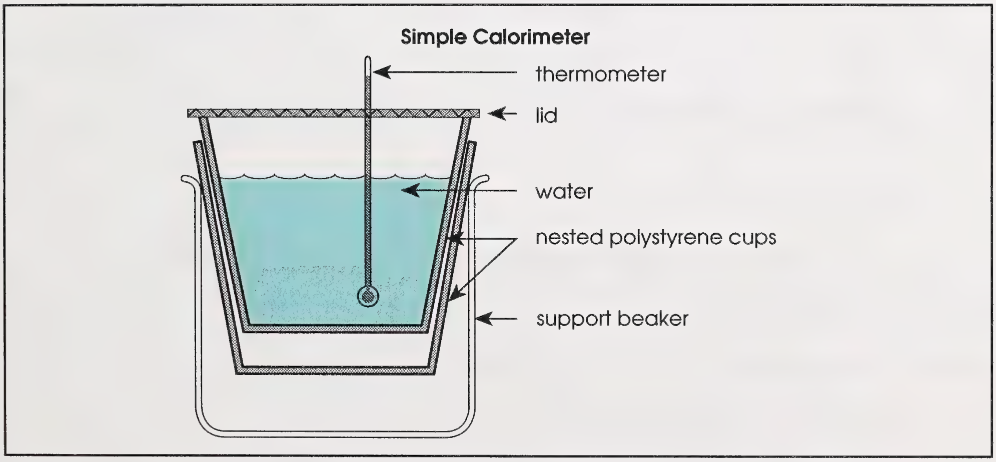
$$= 6.41^\circ\text{C}$$

The observed increase in temperature is 6.41°C.

7. Phase Change → Energy

Chemical Change → Energy

8.



Enrichment

1. When the body temperature is above normal, heat is dissipated by perspiration. Evaporation of sweat from the skin surface causes cooling. This results in lowering your body temperature. You know that the vaporization of water is an endothermic process; therefore the heat transfer results in lowering the temperature of the surface from which the water evaporates. Can you calculate the amount of heat that will be lost by the evaporation of 250 mL of sweat? The answer is 550 kJ.

2. People's activity energy measurements can be done by using a human calorimeter. This is a well-insulated room which makes an isolated system. People live in this room and their energy changes are measured as they do different tasks. Calculations done on energy changes are then used to compare results of different body types, sex, different metabolic rates, etc.

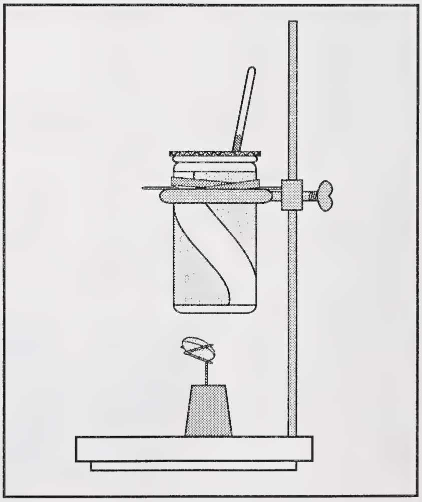
3. An investigation for determining the heat of combustion per gram for a peanut may be as follows.

Investigation: Determining the Heat of Combustion of a Peanut

Materials

- (1) pop can
- thermometer
- matches
- elastic band
- peanuts (unsalted)
- (1) cork
- piece of cardboard
- oven mitts
- (3) paper clips
- water
- ring stand

Procedure



- Use a nail to make four holes on the sides of the pop can near the top. The holes should be evenly spaced.
- Straighten two paper clips and insert them through opposite holes.
- Use the elastic band to hold the clips in place.
- Suspend the calorimeter as shown in the diagram.
- Straighten out one end only of the third paper clip. Carefully secure this end in a cork.
- Add 200 mL of water to the can.
- Punch a hole in the centre of a small piece of cardboard. Place the cardboard on top of the opening of the can. Insert the thermometer through the hole.
- Measure and record the initial temperature of the water.
- Measure and record the initial mass of a peanut.
- Secure the peanut to the paper clip in the cork. Burn the nut and record the final mass of the peanut and the final temperature of the water.

Evidence

initial temperature of water	= 23.8°C
final temperature of water	= 29.3°C
initial mass of peanut	= 0.51 g
final mass of peanut	= 0.29 g
mass of water	= 200.00 g

Analysis

$$\underset{\text{(peanut)}}{\Delta H_c} = \underset{\text{(calorimeter)}}{q}$$

$$\begin{aligned}\Delta H_c &= mc\Delta t \\ &= 0.200\text{ kg} \times \frac{4.19\text{ kJ}}{\text{kg} \bullet {}^\circ\text{C}} \times 5.5^\circ\text{C} \\ &= 4.609\text{ kJ}\end{aligned}$$

The heat energy for 0.22 g of peanut is 4.6 kJ.

The heat of combustion per gram can be calculated as follows:

$$\frac{4.609\text{ kJ}}{0.22\text{ g}} = 21\ \frac{\text{kJ}}{\text{g}}$$

The heat of combustion for the peanut is 21 kJ/g.

Evaluation

Using 23 kJ/g as the accepted value, calculate your percent error.

$$\begin{aligned}\%\text{ error} &= \frac{|\text{experimental value} - \text{accepted value}|}{|\text{accepted value}|} \times 100\% \\ &= \frac{|21\text{ g} - 23\text{ g}|}{|23\text{ g}|} \times 100\% \\ &= 8.7\%\end{aligned}$$

The percent error is 8.7%.

The design of the investigation is considered acceptable even though a large source of error would be the heat lost to the surroundings.

Chemistry 30

Student Module Booklet
Module 1

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