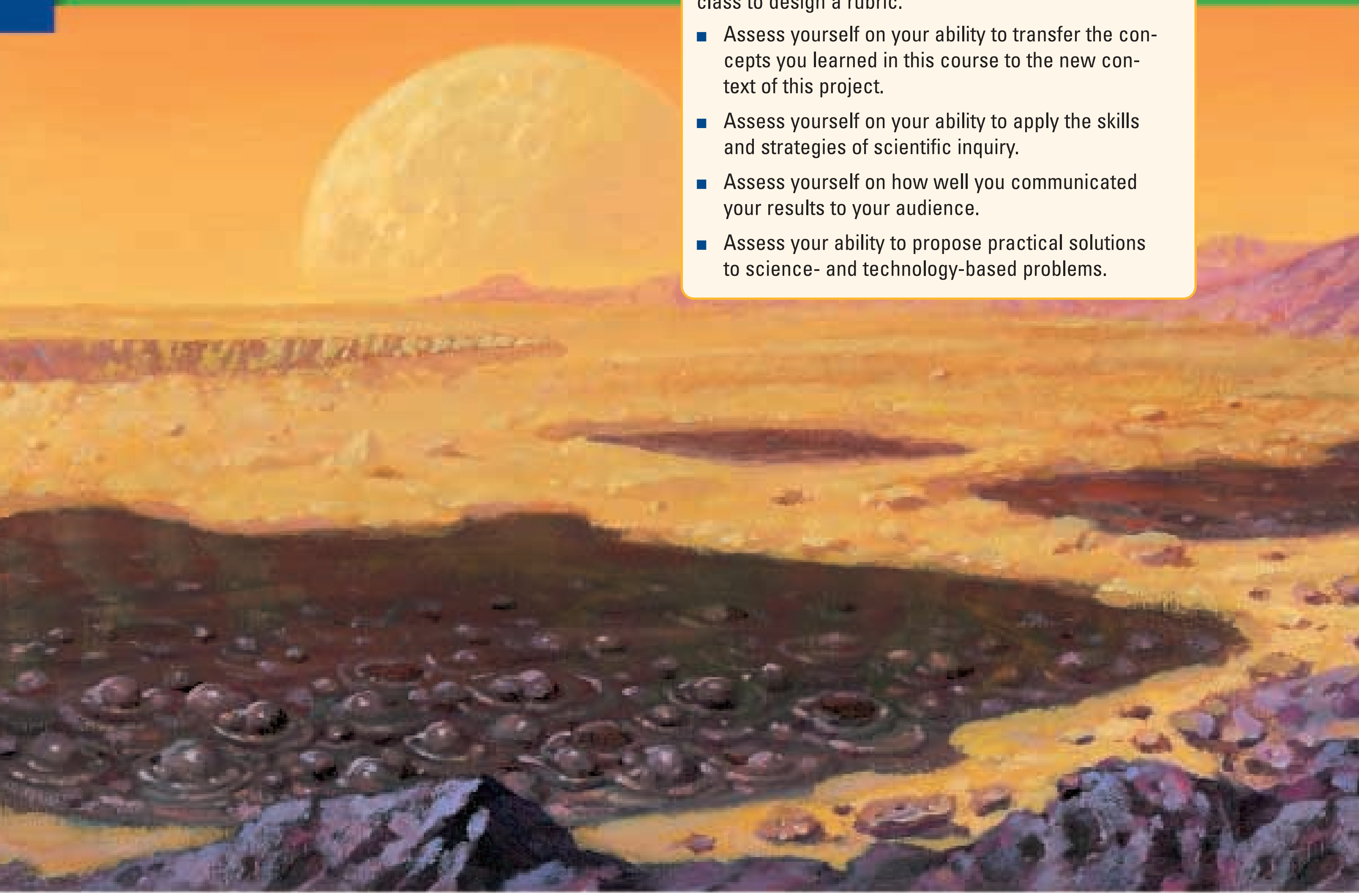


Assessment

Before starting this performance task, work with your class to design a rubric.

- Assess yourself on your ability to transfer the concepts you learned in this course to the new context of this project.
- Assess yourself on your ability to apply the skills and strategies of scientific inquiry.
- Assess yourself on how well you communicated your results to your audience.
- Assess your ability to propose practical solutions to science- and technology-based problems.

Planet Unknown

It is the year 3000, and space travel is commonplace. Nearly one trillion human beings inhabit the Milky Way galaxy now. They reside on thousands of planets that have been made habitable. You are part of a scientific team that has been sent to a newly discovered planet. Your team must analyse the resources present on the planet. You will also decide on the technological processes needed to make the planet a safe place to live. This will involve removing dangerous toxins from the environment, and identifying possible sources of fuel, oxygen, water, and food.

The newly discovered planet has an insulating atmosphere and temperature range similar to Earth's. Each day on the planet is 25 Earth hours long. Every day contains 8 hours of bright sunlight. However, the planet has no ocean, no surface water, and no atmospheric water at all. There is evidence that plant life once existed on this planet. Without surface water, however, there are no plants living on the planet's surface at the present time. A small population of bacteria may be present.

One side of the planet contains a dry and rocky desert, covered in part by a large crater. A thick layer of rock covers the other side of the planet. Under this rocky surface runs a wide network of lava-tube tunnels. Scientists hypothesize that a very large meteor may have struck the planet at one time. The meteor knocked off a chunk of the planet. This chunk now orbits the planet as a moon.

CHECKPOINT

Choose a name for the planet you will explore.

Scientists believe that the enormous heat of this collision decomposed all surface water into hydrogen and oxygen gases. This explains the lack of surface water on the planet. The heat also triggered massive volcanic eruptions. These eruptions resulted in the rocky surface and lava tunnels that cover half the planet.

Fortunately, organic dirt deposits still exist underground, in pockets beneath the lava rock. These dirt deposits would be useful for growing food. A sufficient air supply, plant nutrients, and light will also be necessary in order to grow food.

This challenge comprises five parts, each featuring a unique challenge of its own. Each part reflects the content of a unit from the *Chemistry 11* course you have completed. As you work through the parts, you will apply your knowledge from this chemistry course to make this planet habitable. CAUTION **In any hands-on investigation, carefully consider and carry out all necessary safety precautions**.

Part 1: Trends in Elements

Preview

In Part 1, you will use the skills and content you learned in Unit 1, Matter and Chemical Bonding. In particular, you will be applying your knowledge of elements and the periodic table.

Your science team has discovered some elemental metals on the planet. After testing each element, you have obtained the information given in the data chart below. You have not yet been able to obtain the atomic masses. In addition, these are preliminary tests, so the degree of accuracy is not high. However, you now have enough information to analyse the periodic trends of these new elements.

	Atomic radius (nm)	Observations	Electronegativity (Pauling)	Ionization energy (kJ/mol)	Melting point (K)
A	0.164	silvery white; turns yellow or pinkish in air	1.37	632	1801
B	0.180	lustrous, silver, metallic	1.20	614	1784
C	0.188	silvery white; can be cut with a knife	1.11	537	1188
D	0.189	silver metal; radioactive	1.10	492	1330
E	0.183	soft, silver, malleable, and ductile; gives an intense yellow colour when used as a component in glass	1.12	523	1211
F	0.182	bright silver, metallic; gives a violet, wine red, or grey colour when used as a component	1.13	532	1295
G	0.181	the salts of the metal glow pale blue or green in the dark; radioactive	1.15	537	1321
H	0.180	bright silver; stable in air; absorbs infrared light when used as a component in glass	1.17	545	1352
I	0.199	silver metal	1.19	548	1099
J	0.180	silver metal	1.20	596	1580

mind STRETCH

One of the geologists on your team finds some fossilized wood on the planet. She attempts to find the age of the wood using carbon dating. In carbon dating, the relative amounts of carbon isotopes are compared. Since carbon isotopes decay at a regular rate, this information can be used to find the age of carbon compounds. However, the isotopic ratios of carbon on this planet are different from those on Earth. The isotopic ratios of carbon on this planet are 80.2 % ^{12}C, 19.3% ^{13}C, and 0.5% ^{14}C.

(a) What are the isotopic ratios of carbon on Earth?

(b) What is the average molar mass of carbon on the unknown planet?

Challenge

Analyse any periodic trends that appear in the data. Trends will be similar to those in Earth's periodic table. (**Hint:** Part of the list belongs to a group. Another part of the list belongs to a period.)

1. I Explain the periodic trends seen in the chart. How does your explanation correlate with Earth's periodic table? Which trends on Earth's periodic table increase from left to right? Which trends generally increase from top to bottom? Which data do not seem to fit the trend? Can you suggest a possible explanation?

2. K/U Which metal is more reactive, A or C? Which metal is the least reactive, F or G? How do you know?

3. C Assume that these metals are also present on Earth. Use Earth's periodic table to identify a possible element on Earth that matches each unknown element. Explain your reasoning.

Part 2: Growing Food

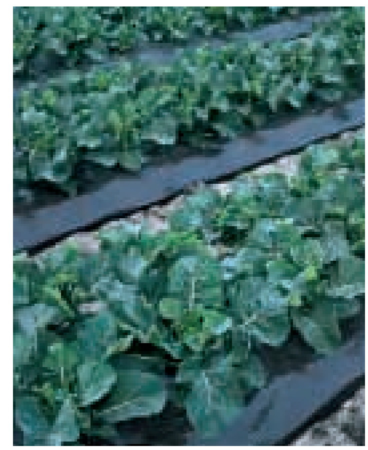
In your explorations, your team discovers a particularly large underground cavern. The cavern has a steady water source seeping out of phosphate rock. This trickling water picks up a weak concentration of phosphate ions as it filters through the rock. There is plenty of soil in this cavern, although extra plant nutrients will need to be added on a regular basis as crops are grown and harvested. This cavern may be an excellent site for growing vegetables and other plants. A source of light will be needed.

Preview

In Part 2, you will apply the skills you learned in Unit 2, Quantities in Chemical Reactions.

Challenge

To grow sufficient crops, you will need large amounts of calcium phosphate fertilizer. You can make this compound by combining the phosphate solution in the stream with calcium cations. Simulate this reaction in the laboratory. Design a procedure to find the mass of dry calcium phosphate precipitate. Mix 50 mL of a 0.10 mol/L aqueous solution of sodium phosphate with sufficient calcium nitrate to obtain a precipitate. Filter the precipitate, dry it, and determine its mass.



1. K/U Write the balanced chemical equation and net ionic equation for the reaction described in the Challenge.
2. I Write up a procedure for your investigation, and have your teacher approve it before you begin. Before starting, discuss appropriate safety precautions with your teacher. Wear eye protection. Wash your hands after any contact with chemicals.
3. C Prepare a detailed report to share your findings. Include all of your observations and answers to the questions in Part 2.
4. I In your report, compare the theoretical yield with the actual yield of the product. Identify possible sources of error in your procedure.
5. I If time permits, modify your procedure to improve your results. Keep a detailed record of the changes you made to the procedure, the observed benefits, and the new percent yields obtained.

Think and Research

1. I Using the reactant amounts from your experiment, what mass of sodium nitrate would you expect to get from the reaction? How could you collect this product to test your calculations?
2. I Show the calculations you used to find the amount of calcium nitrate necessary to react with the phosphate solution.
3. I If 600 L of 0.10 mol/L solution of sodium phosphate were reacted with 10 kg of calcium nitrate, what would the limiting reagent be?

Extension

4. MC What other modifications will you need to make the cavern suitable for growing plants? For example, would you need to add other nutrients as fertilizer? Do sources of these nutrients exist on the planet already? Write the chemical equations for the reactions.

Part 3: What's in the Water?

Preview

This part will call upon what you learned in Unit 3, Solutions and Solubility. In particular, you will review solutions, titrations, and acid-base chemistry.

Life as we know it is impossible without water. Thus it is essential to establish a good water source. Although there is no surface water of any kind, the planet does have water—underground! Since this water is constantly filtered through underground rocks and soil, it contains many dissolved substances. Some of these substances may be dangerous to human health. These materials will have to be removed in order to obtain clean water. How can you find out what substances are present in the water?

Challenge

Your teacher will give you a sample of water representing the planet's underground water. Analyse the chemical composition of the water sample. (Note that the sample you have may not be the same as the samples of your classmates.)

There are several methods you can use to analyse specific components of your sample. These may involve:

- titration
- precipitation
- acid-base tests
- evaporation
- distillation

1 I Choose one or more methods to analyse your sample. Your teacher will give you further guidance on the methods that are most useful for your specific sample.

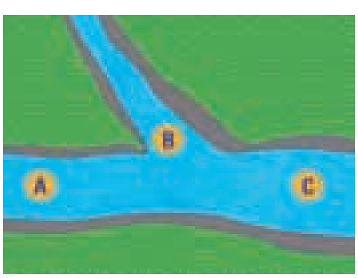
2 I Write up a procedure for your investigation, and have your teacher approve it before you begin. Before starting, discuss appropriate safety precautions with your teacher. Wear eye protection, gloves, and an apron.

3 C After you have analysed your sample, prepare a detailed report.

Think and Research

1 I What else might you need to know about your water sample? How could you find out?

2 C Write a brief report that lists the different methods used to clean water on Earth. Explain how each method works. Remember to include diagrams and any relevant balanced chemical equations.



At point A, the river is clean. At point C, however, the river is contaminated with the toxic nitrite ion. How can you contain the pollution at point B?

Extension

3 I A large river of clean, fresh water flows through the largest lava tunnel. At point B, a small river flows into the larger river. This smaller river contains dangerous levels of toxic nitrite ions (NO_2^-). To prevent the smaller river from contaminating the larger one, you have decided to limit the flow of the small river. Safety standards permit a maximum of 3.2 mg of nitrite per litre of water. The flow of the larger river is 1.2×10^4 L/s. The concentration of nitrite in the smaller river is 51.2 ppm. What amount of water (in L/s) can be allowed to enter the larger river from the smaller river?

Part 4: Planetary Gases

The atmosphere of the planet is composed of the following gases:

argon (49.2%)	carbon dioxide (1.3%)
oxygen (30.8%)	ammonia (0.9%)
nitrogen (14.6%)	dinitrogen oxide (0.5%)
hydrogen cyanide (2.3%)	hydrogen sulfide (0.4%)

Although the atmosphere contains oxygen, it also contains gases that are toxic to humans. Eventually, you hope to build a settlement inside a huge synthetic bubble with its own safe atmospheric mixture of gases. First, your team must find an alternate source of oxygen gas. On Earth, plants supply oxygen through the process of photosynthesis. This may be the best method of providing a constant supply of breathable air for the settlement bubble on the new planet. But do plants give off pure oxygen, or a mixture of gases? How much oxygen does a certain mass of plants give off?

Challenge

Design an investigation to collect the gas given off by a certain mass of *Rotela* water plants. Find the mass and volume of the gas. Use this data to calculate the molar mass and molar volume of the gas. (**Note:** This experiment will take several days to do correctly. If possible, do multiple trials.)

1. K/U Write the balanced equations for photosynthesis and for cellular respiration.
2. I Write up a procedure for your investigation, and have your teacher approve it before you begin. Before starting, discuss appropriate safety precautions with your teacher. Wash your hands after handling the *Rotela* plants.
3. I Carry out your procedure. Use the volume and the mass of the gas, along with the temperature of the water and pressure of the room, to calculate the average molar mass and the molar volume of the gas.
4. C Prepare a detailed report to share your findings. In your report, compare the molar mass of the gas you calculated to the molar mass of oxygen. Explain the difference between these values. Identify possible sources of error in your procedure.

Think and Research

1. I Your team sends a balloon 50 m up into the atmosphere of the planet. The balloon contains 20.3 mol of helium gas. At a temperature of 313 K, the balloon has a volume of 614 L. Assume that the universal gas constant, R, has the same value as it would on Earth. What is the atmospheric pressure on this planet at 313 K? What is it at 0°C?
2. I Use the pressure at 0°C from the previous question. What is the partial pressure of each of the components of the atmosphere?
3. I What volume will 1.44 kg of oxygen gas occupy at the planet's atmospheric pressure? (Assume a temperature of 0°C.)
4. I Rearrange the ideal gas equation to calculate the molar volume for any ideal gas on this planet at 0°C.

Preview

In this part, you will use the skills you learned in Unit 4, Gases and Atmospheric Chemistry.

mind STRETCH

During cellular respiration, plant cells use oxygen to break down food into energy. Thus, plants take in oxygen and give off carbon dioxide. When in the presence of light, plants also take in carbon dioxide and give off oxygen during photosynthesis. Does cellular respiration use up the same amount of oxygen that is given off by photosynthesis? Do plants give off a net amount of oxygen, carbon dioxide, or a combination of the two? Do research to find out.

PROBLEM TIP

(a) Photosynthesis only occurs during the hours of sunlight. At night, only respiration is taking place. How might this affect your investigation?

(b) Remember to include the vapour pressure of water in your calculations.

(c) Did the temperature or pressure change over the course of the experiment? Design your investigation to include some checks on this data.

Part 5: Finding Fuel

Preview

This part draws upon the skills and concepts you learned in Unit 5. Your main focus will be hydrocarbon fuels and the heat equation.

While exploring the lava tunnels, your team discovers a coal-like substance. This substance may have originated as a fungus growing in underground caves. When the meteor hit the planet, the caves collapsed. Over millions of years, the pressure of the rock converted the organic material into a fossil fuel.

Challenge

Your teacher will give you a sample of the coal-like substance discovered on the planet. Design a calorimeter to measure the heat of combustion of this substance. Decide whether this substance will be useful as a fuel.

1. I Write up a procedure for your investigation, and have your teacher approve it before you begin. Before starting, discuss appropriate safety precautions with your teacher. Wear eye protection, and use care with hot surfaces.
2. I Carry out your procedure. Calculate the heat of combustion per gram of your sample.
3. C Prepare a detailed report to share your findings.

Think and Research

Your team has also discovered large pools of hydrocarbon oils on the surface of the planet. The hydrocarbons seem similar to hydrocarbons on Earth, and may have been formed in the same way. When analysed, the oil proves to be composed entirely of compounds with the molecular formula C_7H_{16}.

1. K/U How might these hydrocarbon oils have originated?
2. K/U Draw and name all the possible isomers that have this molecular formula.
3. MC What might be done with the open pools of oil? Give two or three possibilities.
4. I On another area of the planet, your team discovers a vent with gas seeping from it. The gas is found to be 81.7% carbon and 18.3% hydrogen by mass. The molecular mass of the gas is 44.11 g/mol. What is the formula of the compound? Name the gas. Draw the structural formula of the compound.
5. MC Suppose you decide to use the coal-like substance and the pools of oil as fuel. How might your use of these fuels affect the environment on the planet? What precautions will you take to prevent environmental damage?

Part 6: Final Presentation

What other challenges might humans face while developing this planet? You may want to investigate a different problem. For example:

Unit 1

- Suppose matter on the new planet were not composed of electrons, protons, and neutrons. Devise a new atomic theory of your own. Explain how it works in "real life" on the planet. Make up a small, functional periodic table with new, imaginary elements.
- Develop rules that explain the bonding between your new atoms. How do these rules affect the reactivity of your elements and structure of your compounds?

Unit 2

- Suggest reactions that may make life easier on the planet. Research and perform these reactions in the laboratory. Write balanced equations, and calculate percent yields in moles and in grams. Explain the purpose of these reactions in the settlers lives.

Unit 3

- Suggest one or more substances that may already be dissolved in the water on the newly-discovered planet. Test the solubility of the substance and plot solubility curves for the solute in water. Explain why the substance is in the water, and how the substance will affect the life of the settlers. For example, is it safe to drink? How can it be removed from the water? Once extracted, can it be used for anything else?

Unit 4

- Choose a reaction producing a gas that may be useful to settlers on the new planet. Research the reaction, then carry it out in the laboratory. Collect the gas produced and determine its molar volume.

Unit 5

- Choose three of these compounds: NaOH, anhydrous $CaCl_2$, LiBr, HCl, anhydrous Na_2SO_4, $AgNO_3$, KI, NH_4NO_3, $Na_2CO_3 \cdot 10H_2O$, and $KMnO_4$. Design an investigation to measure and compare the heats of solution per mole of these chemicals. Choose one chemical based on its heat of solution, and its safety for everyday use. Come up with a plan or device that uses the heating or cooling effect produced by this process to help the planet's settlers remain comfortable.

Your presentation After preparing lab reports on one or more sections of this Course Challenge, you will share your results in a class presentation. Assume this presentation is being made to the Canadian Minister of Emigration, the Canadian Minister of the Economy, and a group of business people who may wish to invest in the development of the planet.

- Provide your audience with solutions to the different scenarios and problems you investigated. Be prepared to respond to other possible questions and problems your audience (your class and teacher) may raise.
- To enhance your presentation, try to include two or more of the following: posters, brochures, drama, music, lab demonstrations, video or audio clips, charts or graphs, surveys, models, multimedia, or web pages with links.

Web LINK

If you have time, work as a class to create a web site based on this Course Challenge. Create a virtual tour of your planet's resources, projected living spaces, and scientific adaptations. Share your findings with other grade eleven classes in your province over the Internet.