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Computers in Chemistry

Making Chemical Measurements Using the LabWorks Interface and a Handheld Graphing Calculator

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A hand-held calculator with serial communication capability and a graphics display provides a low-cost solution….

The LabWorks learning system is a computer-controlled data acquisition interface that allows students to quickly obtain and analyze chemistry data. This article describes how the LabWorks interface can be controlled with an HP 48G hand-held calculator rather than a personal computer. The calculator provides users with the same automated data acquisition as if a computer were controlling the interface, but it costs less and requires less maintenance and laboratory bench space. The types of measurements made by the system are discussed and a sample experiment described. Student data and comments are also presented.

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Introduction

Technology is available to facilitate higher learning in introductory chemistry laboratories, but obstacles exist that prevent technology's proper employment. Laboratory instructors may continue to use "proven" teaching methods because the technological tools necessary for higher learning are either too expensive, too difficult to understand, or both. The LabWorks (Manufacured by SCI Technologies, Bozeman, MT) learning system is an affordable and powerful educational tool [1, 2], but it requires a personal computer (PC) to control its data acquisition interface. Schools with limited space or budgets may not be able to support a large number of computers in their classrooms. An alternative to using a PC to control the LabWorks interface is the Hewlett Packard HP 48 series of hand-held calculators.

HP 48 calculators have the ability to communicate with the LabWorks II interface via serial link. Like PCs, the calculators can send commands and receive LabWorks-acquired data. The data can also be stored and displayed in both graphical and textual formats. At $100 per unit, HP 48 calculators are less expensive than PCs. Calculators also occupy much less bench space than a personal computer. This article discusses the benefits of using this alternative to personal computers, specific advantages and disadvantages of calculators versus PCs for interface control, and gives a sample experiment that employs a calculator-controlled LabWorks interface.

Considerations for Calculator Control

The purchasing and implementing of technology requires time and money, which needs to be spent up front to reap educational benefits later. Any advances that decrease these initial costs will make the technology available to more students. Once schools decide to implement the LabWorks system, the laboratory administrator must: (1) purchase the interfaces and sensor packages, (2) acquire personal computers or other controlling devices, and (3) find laboratory space for the equipment.

When looking for the computers to control the LabWorks system, laboratory administrators do not necessarily have to budget for expensive, top-line models. Many college departments and local businesses periodically upgrade their computer systems. This makes older-generation PCs available at extremely low cost. The DOS version of the LabWorks software runs very well on older PCs [3] and it is relatively easy for a budget-limited laboratory administrator to obtain these computers second-hand.

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Finding laboratory space for the equipment is often more difficult than acquiring it. All but the most recently built chemistry laboratories were designed without allowing space for computer central processing units, monitors, and keyboards. If not carefully planned, the arrangement of the required equipment will leave insufficient bench space for the chemistry experiments themselves. Montana State University and the U.S. Air Force Academy have developed innovative, space-conserving solutions [4].

A hand-held calculator with serial communication capability and a graphics display provides a low-cost solution to requirements 2 and 3. Calculators with these capabilities cost much less than computers, and they only occupy a few square inches of desk space. Furthermore, the control software can be copied to student-owned calculators, reducing or eliminating the need for schools to purchase and maintain calculators for each student or laboratory station.

Hewlett Packard Corporation manufactures a cable that enables their HP 48 calculators to connect to PCs via a 9-pin serial port. The LabWorks II interface also communicates with PCs using a 9-pin serial port. A null-modem adapter is also necessary to allow the calculator and interface to communicate with each other.

Making Measurements

The LabWorks II interface uses a 12-bit analog-to-digital converter (ADC) to measure data, such as electrical current and voltage. The interface also measures digital information using a timer, event counter, or photogate. This data is then sent to a personal computer to be stored and analyzed. The LabWorks interface also uses a 12-bit digital-to-analog converter (DAC) to provide specific voltages for measurements and experiment control. The HP 48G calculator is able to receive and store data from all of the LabWorks sources. (See Figure 1.) The details of how the HP 48G communicates with the LabWorks interface will be described in a later article.

Sample Experiment Using the Calculator and Interface

Concept and Background

An experiment that has been written for the HP 48 and the LabWorks interface is called, “Exploring the Chemistry of Gases in Solution.” In this inquiry-based

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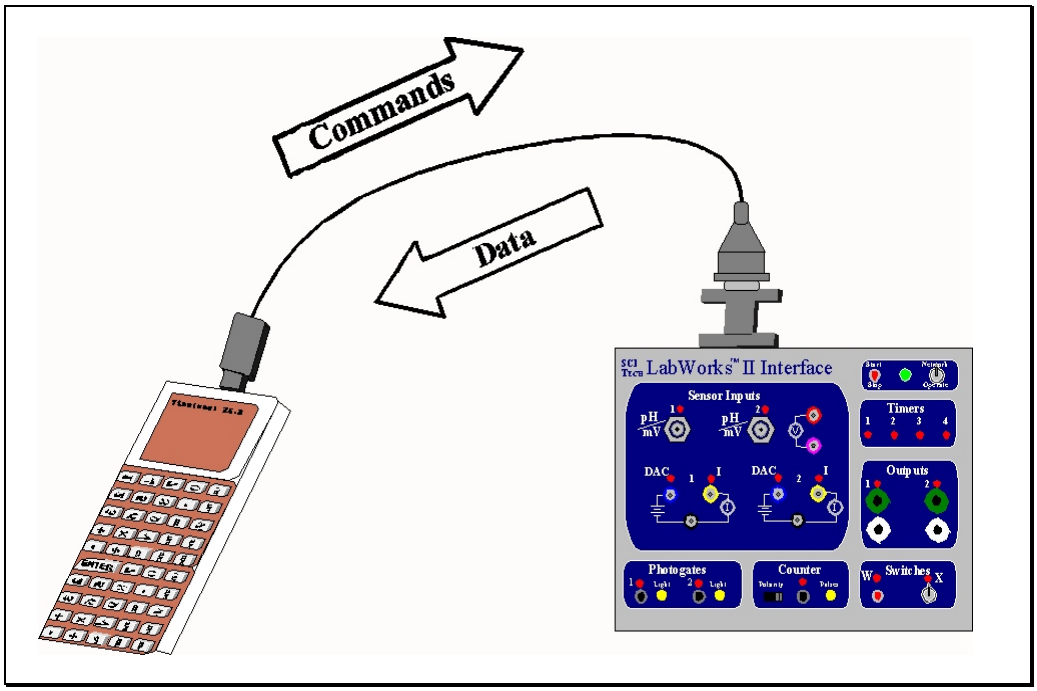

FIGURE 1. THE HP 48/LABWORKS CONNECTION.

experiment, students measure the pH of carbonated water; cola; and optionally, lemon-lime soda. Dissolved CO_2 causes the water to be acidic due to formation of carbonic acid.

$$H_2O + CO_2 \rightleftharpoons H_2CO_3$$

Heating the carbonated water drives off the CO_2, raising the pH of the solution. Cola also contains carbonated water and is acidic. Heating cola to remove its CO_2 causes its pH to decrease. Students are asked to explain the apparently disparate behavior. (See Figure 2.)

With proper background and encouragement, students will realize that the bicarbonate anion acts to buffer the phosphoric acid that is present in cola.

Student Procedures

First, students must connect the calculator to the interface using the Hewlett Packard serial connection cable and a null-modem adapter. Next, a standard pH electrode must be inserted into the pH/mV1 input of the LabWorks interface.

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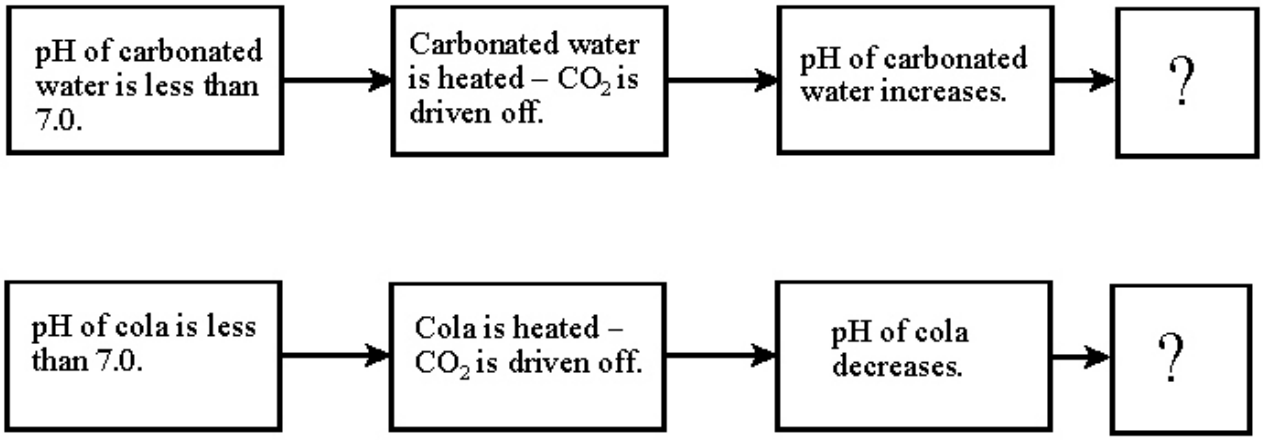

FIGURE 2. ACTIVITY CONCEPT CHART FOR "EXPLORING THE CHEMISTRY OF GASES IN SOLUTION." HEATING BOTH CARBONATED WATER AND COLA PRODUCES DIFFERENT PH CHANGES. STUDENTS MUST EXPLAIN WHY THIS IS SO.

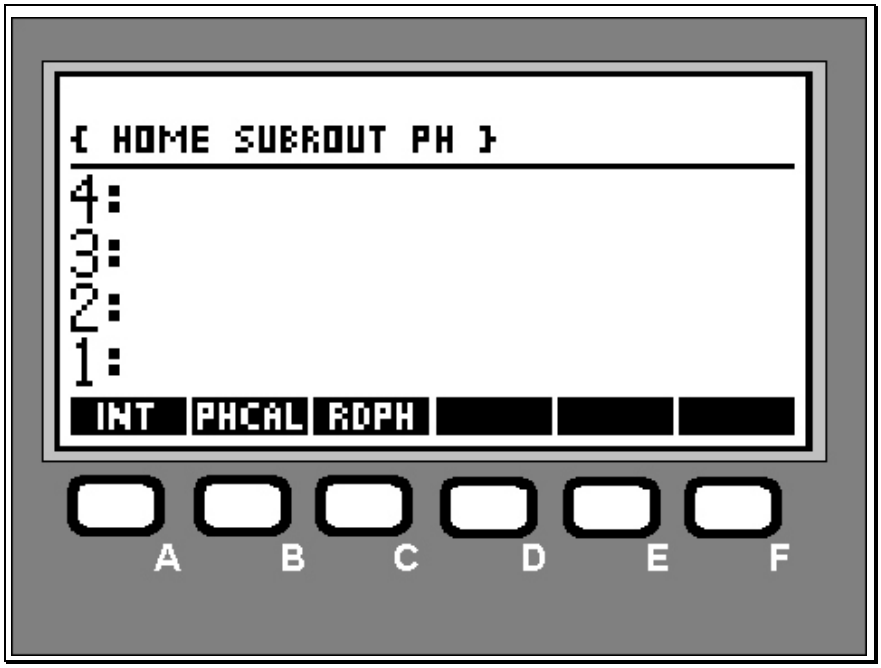

FIGURE 3. HOW TO ACCESS HP 48 PROGRAMS.

To calibrate the pH probe, students run a calibration program. Both the calibration and data-acquisition programs are activated by pressing the program buttons on the HP 48 keypad. Figure 3 shows an HP 48 screen shot with the program buttons.

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FIGURE 4. pH PROBE CALIBRATION INSTRUCTIONS.

Students press the B key to start the PHCAL calibration program. They are then prompted to insert the pH probe in a known buffer solution and press OK as shown in Figure 4. The next screen prompts the students to enter the pH value of the buffer they are using to calibrate. A single calibration point is all that is needed for pH probes because standard probes change 57 mV per pH unit.

To make the measurements necessary for this experiment, the RDPH program is run. This program provides a continuous pH reading for the different solutions.

Student Results and Comments

Data for this experiment is qualitative rather than quantitative. Students see that the pH of their solutions are less than 7.0, and that the pH values change after the solutions have been heated to drive out the CO_2. Carbonated water gives pH values from 5.5–6.0, and cola's pH ranges from 1.5–2.0.

From a survey given to introductory chemistry (Chem 121, Spring 1996) students at Montana State University, students found the HP 48/LabWorks system easy to use. Students who had used both the computer-controlled interface and the HP 48-controlled interface preferred the computer because of the calculator's small display and marginal user-friendliness.

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Conclusions and Future Work

The HP 48 calculator is not as capable of controlling the LabWorks interface or as user-friendly as a personal computer; however, this technology allows the introduction of automated data acquisition into laboratories that do not have the money or space for personal computers.

Future work in this area includes allowing for students to design calculator-controlled experiments, rather than only run prewritten programs. Other platforms, such as hand-held Windows CE computers and TI calculators, are presently being investigated as controllers for the LabWorks interface.

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