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**TEACHING SYSTEM**

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## ABSTRACT

A teaching system comprises a server and a network interface for communicatively connecting the server to a client device remote from the server over a network. The client device comprises a visual display and a user input device. A web server is executed on the server that hosts an interactive website that when accessed by the client device over the network causes the client device to render a chemistry-related numerical problem question on the visual display. The problem question comprises one or more chemical substances, a chemical or physical transformation involving the chemical substances and one or more known physical quantities relating to the chemical substances and/or the chemical or physical transformation. The client device is also caused to render one or more UI elements that enable a user to identify and note the known physical quantities and at least one unknown physical quantity that is required to be calculated by the problem question, and to receive and render the known physical quantities and the unknown physical quantity noted by the user using the UI elements. The client device is caused to render a sequence of numerical calculations that, when performed in sequential order by the user, result in a numerical value being calculated for the unknown physical quantity, wherein (i) each of the numerical calculations transforms one or more input parameters into an output value, (ii) each of the input parameters comprises a quantity based or derived from one of the known physical quantities or an output value calculated for a previous numerical calculation, and (iii) at least one of the numerical calculations in the sequence comprises calculating a number of moles of an amount of, or a change in an amount of, at least one of the chemical substances due to the chemical or physical transformation. The client device receives user input corresponding to the relevant input parameters and output value of each numerical calculation and renders user feedback that indicates whether or not the numerical value calculated by the user for the unknown physical quantity is correct.

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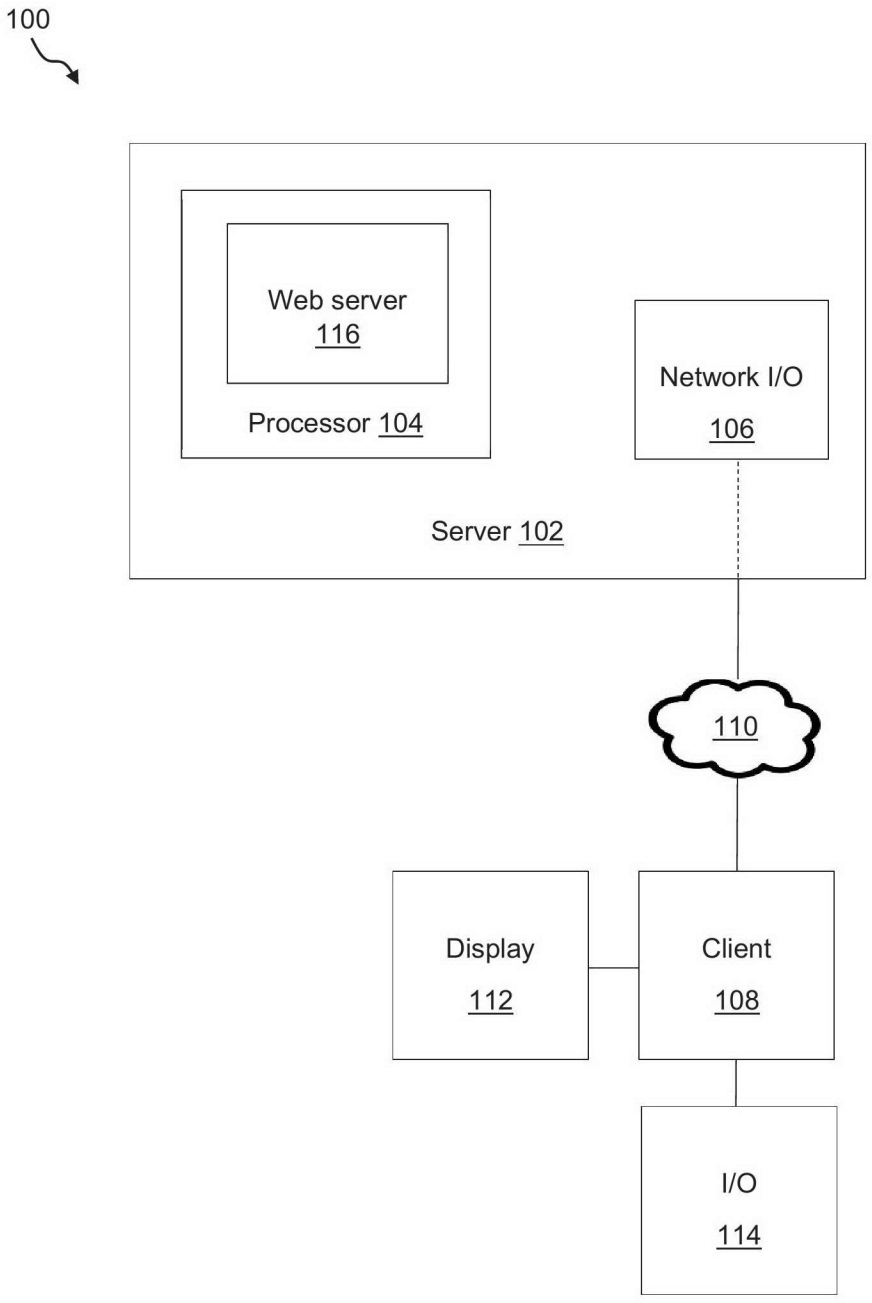


Figure 1

# TEACHING SYSTEM

## Field

[0001] The present invention relates to teaching and, more particularly, to a system for teaching chemistry.

## Background

[0002] Stoichiometry is a branch of chemistry that deals with quantitative relationships between chemical substances undergoing physical or chemical change. In particular, stoichiometry involves the calculation of physical quantities of chemical substances, or relative quantities between chemical substances, participating in chemical and physical transformations. For example, stoichiometry can be used to calculate quantities of reactants and products in a chemical reaction.

[0003] For many chemistry students, stoichiometry is difficult to learn and requires a substantial amount of time and effort to master. This is, in part, because stoichiometry requires the student to learn and apply abstract mathematical principles and perform algebraic manipulation to derive quantitative solutions. The skills and knowledge required to perform stoichiometric calculations may be unfamiliar to chemistry students and the subject is often perceived as being in stark contrast to other topics covered in a traditional chemistry curriculum.

[0004] Stoichiometry is taught in educational institutions by firstly teaching to a student the scientific theories and principles that underpin a set of particular chemical or physical transformations. Various applied mathematical techniques that may be used to calculate quantitative outcomes involving these theories and principles are then explained. The student is then shown various example stoichiometric problems and solutions that put all of the foregoing into practice.

The student is finally provided with various stoichiometric problems and asked to calculate their own solutions which are reviewed and marked by the tutor. These steps are repeated until the tutor is satisfied that the student is proficient and sufficiently versed with the knowledge and skills required to carry out stoichiometric calculations to the standard required by the curriculum.

[0005] The above teaching method requires the tutor to be available to assist the student at all stages of the teaching process and it does not enable the student to perform effective self-directed study. Further, stoichiometric problem questions commonly require the student to identify and understand the interplay between multiple different physical relationships and chemical principles. The student may, therefore, be required to perform a chain of interdependent calculations to arrive at the final correct solution. Identifying and applying the relevant interdependencies can be tricky and known teaching methods do not provide students with an effective way to acquire this skill. Further, stoichiometric problem questions often express quantities of various chemical substances in different units. A student can easily become lost or confused when performing a chain of stoichiometric calculations that involve multiple different units.

[0006] It is against this background that the present invention has been developed.

**Summary**

[0007] According to the present invention, there is provided a teaching system comprising:

a server with at least one processor;

a network interface for communicatively connecting the server to at least one client device remote from the server over a computer network, wherein the client device comprises a visual display and a user input device; and

a web server executed by the processor of the server, wherein the web server hosts an interactive website that when accessed by the client device over the computer network causes the client device to:

render a chemistry-related numerical problem question on the visual display, wherein the problem question comprises one or more chemical substances, a chemical or physical transformation involving the chemical substances and one or more known physical quantities relating to the chemical substances and/or the chemical or physical transformation;

render one or more UI elements on the visual display, wherein the UI elements enable a user of the client device to identify and note the known physical quantities and at least one unknown physical quantity that is required to be calculated by the problem question;

receive and render on the visual display the known physical quantities and the unknown physical quantity noted by the user using the UI elements;

render a sequence of numerical calculations on the visual display, wherein the numerical calculations correspond to a sequence of numerical sub-problems that, when performed in sequential order by the user, result in a numerical value being calculated for the unknown physical quantity, wherein:

each of the numerical calculations transforms one or more input

parameters into an output value;

each of the input parameters comprises a quantity based or derived from one of the known physical quantities or an output value calculated for a previous numerical calculation in the sequence; and

at least one of the numerical calculations in the sequence comprises calculating a number of moles of an amount of, or a

change in an amount of, at least one of the chemical substances due to the chemical or physical transformation;

receive, by the input device, user input submitted by the user that corresponds to the relevant input parameters and output value of each of the numerical calculations; and

render user feedback on the visual display, wherein the user feedback indicates whether or not the numerical value calculated by the user for the unknown physical quantity is correct.

[0008] At least one of the numerical calculations in the sequence may involve using a molar mass of a particular chemical substance in the chemical substances to calculate a number of moles of, or a change in an amount of, the particular chemical substance due to the chemical or physical transformation.

[0009] The problem question may further comprise a chemical reaction involving one or more of the chemical substances, wherein each of the chemical substances participating in the chemical reaction is an element, a molecule, an ion or a compound, and wherein one of more of the input parameters of the numerical calculations comprises a numerical value derived from one or more of the chemical substances participating in the chemical reaction.

[0010] The client device may further be caused to:

render a chemical equation on the visual display, wherein the chemical equation represents the chemical reaction;

render one or more UI elements on the visual display that require and allow the user to transform the chemical equation into a balanced chemical equation; and

render the sequence of numerical calculations on the visual display such that one of more of the input parameters comprises a stoichiometric coefficient of the balanced chemical equation.

[0011] The teaching system may be configured such that:

the web server comprises data identifying a first numerical value that is provided, or that is required to be calculated, by the problem question, wherein the first numerical value is used as an input parameter of a second numerical calculation in the sequence;

the web server comprises data encoding a symbol or graphical marker that is unique in visual appearance; and

the client device is further caused to:

display a first instance of the symbol or graphical marker on the visual display at a position that is proximal to where the first numerical value is to be displayed on the visual display; and

display a second instance of the symbol or graphical marker on the visual display at a position that is proximal to where the second input parameter is to be displayed on the visual display, such that the first and second instances signify a relationship between the first numerical value and the second numerical calculation.

[0012] The symbol or graphical marker may have a unique colour.

[0013] The client device may be further caused to:

display the numerical calculations on the visual display in sequential order one by one; and

for each individual numerical calculation in the sequence that has an earlier numerical calculation in the sequence immediately preceding the individual numerical calculation, only display the individual numerical calculation on the visual display after the user has submitted values for the relevant input parameters of the earlier numerical calculation.

[0014] The client device may be further caused to only display the individual numerical calculation on the visual display if the relevant values that are submitted by the user for the relevant input parameters of the earlier numerical calculation are correct.

[0015] The client device may be further caused to only display the individual numerical calculation on the visual display after the user has submitted a value for the relevant output value of the earlier numerical calculation.

[0016] The individual numerical calculation may only be displayed on the visual display if the relevant value that is submitted by the user for the relevant output parameter of the earlier numerical calculation is correct.

[0017] The client device may be further caused to display a range of possible values for the relevant input parameters and/or output value of the individual calculation on the visual display using selectable UI controls, wherein each of the selectable UI controls enables the user to select and submit to the website only one of the relevant possible values.

[0018] The client device may be further caused to display on the visual display a selected value submitted using one of the selectable UI controls in a unique colour, wherein the unique colour corresponds to whether the selected value is correct or incorrect.

[0019] The unique colour may be green if the selected value is correct and red if the selected value is incorrect.

[0020] Each of the selectable UI controls may comprise a drop down menu.

[0021] The client device may be further caused to display all of the numerical calculations on the visual display at the same time, wherein for each individual numerical calculation in the sequence:

a range of possible values for the relevant input parameters and/or output value of the relevant individual calculation are displayed on the visual display using selectable UI controls; and

for each of the selectable UI controls, the user may only select and submit to the website one of the possible values provided in the relevant selectable UI control.

[0022] The teaching system may be configured such that for each individual numerical calculation in the sequence that has an earlier numerical calculation in the sequence immediately preceding the relevant individual numerical calculation, the user may not submit values for the relevant individual numerical calculation to the website unless and until the user has submitted values for the relevant input parameters of the earlier numerical calculation.

[0023] The client device may be further caused to display on the visual display information relating to one or more scientific theories or principles relevant to the problem question.

[0024] The present invention also provides a computer-readable non-transitory medium storing instructions that are executable by a web server hosted on a server, wherein the server comprises a network interface for communicatively connecting the server to at least one client device remote from the server over a computer network, and wherein the client device comprises a visual display and a user input device,

wherein the instructions, when executed by the web server, cause the client device to:

render a chemistry-related numerical problem question on the visual display, wherein the problem question comprises one or more chemical substances, a chemical or physical transformation involving the chemical substances and one or more known physical quantities relating to the chemical substances and/or the chemical or physical transformation;

render one or more UI elements on the visual display, wherein the UI elements enable a user of the client device to identify and note the known physical quantities and at least one unknown physical quantity that is required to be calculated by the problem question;

receive and render on the visual display the known physical quantities and the unknown physical quantity noted by the user using the UI elements;

render a sequence of numerical calculations on the visual display, wherein the numerical calculations correspond to a sequence of numerical sub-problems that, when performed in sequential order by the user, result in a numerical value being calculated for the unknown physical quantity, wherein:

each of the numerical calculations transforms one or more input parameters into an output value;

each of the input parameters comprises a quantity based or derived from one of the known physical quantities or an output value calculated for a previous numerical calculation in the sequence; and

at least one of the numerical calculations in the sequence comprises calculating a number of moles of an amount of, or a change in an amount of, at least one of the chemical substances due to the chemical or physical transformation;

receive, by the input device, user input submitted by the user that corresponds to the relevant input parameters and output value of each of the numerical calculations; and

render user feedback on the visual display, wherein the user feedback indicates whether or not the numerical value calculated by the user for the unknown physical quantity is correct.

## Brief Description of Drawings

[0025] Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a teaching system according to an example embodiment of the invention;

Figure 2 is an example stoichiometry problem question and solution rendered on a visual display of a client device of the system;

Figure 3 is a further example stoichiometry problem question and solution rendered on the visual display; and

Figure 4 is a further stoichiometry problem question and solution rendered on the visual display.

## Description of Embodiments

[0026] Referring to Figure 1, an example embodiment of the present invention provides a teaching system 100. The teaching system 100 comprises a server 102 provided with at least one processor 104 and a network interface 106 for communicatively connecting the server 102 to at least one client device 108 remote from the server 102 over a computer network 110. The client device 108 comprises a visual display 112 and a user input device 114.

[0027] A web server 116 is executed by the processor 104 of the server 102, wherein the web server 116 hosts an interactive website that when accessed by the client device 108 over the computer network 110 causes the client device 108 to render a chemistry-related numerical problem question on the visual display 112, wherein the problem question comprises one or more chemical substances, a chemical or physical transformation involving the chemical substances and one or more known physical quantities relating to the chemical substances and/or the chemical or physical transformation. The client device

108 is also caused to render one or more UI elements on the visual display 112, wherein the UI elements enable a user of the client device 108 to identify and note the known physical quantities and at least one unknown physical quantity that is required to be calculated by the problem question, and to receive and render on the visual display 112 the known physical quantities and the unknown physical quantity noted by the user using the UI elements.

[0028] The client device 108 is also caused to render a sequence of numerical calculations on the visual display 112. The numerical calculations correspond to a sequence of numerical sub-problems that, when performed in sequential order by the user, result in a numerical value being calculated for the unknown physical quantity, wherein (i) each of the numerical calculations transforms one or more input parameters into an output value, (ii) each of the input parameters comprises a quantity based or derived from one of the known physical quantities or an output value calculated for a previous numerical calculation in the sequence, and (iii) at least one of the numerical calculations in the sequence comprises calculating a number of moles of an amount of, or a change in an amount of, at least one of the chemical substances due to the chemical or physical transformation.

[0029] The client device 108 is also caused to receive, by the input device 114, user input submitted by the user that corresponds to the relevant input parameters and output value of each of the numerical calculations, and then render user feedback on the visual display 112 that indicates whether or not the numerical value calculated by the user for the unknown physical quantity is correct.

[0030] Figure 2 depicts an example stoichiometric problem question 200 that may be presented on a single screen 202 of the visual display 112 to a school student, or similar user, of the system 100. The problem question 200 may comprise a description of a chemical reaction 204 which involves a specified

quantity of potassium hydroxide reacting with an excess of sulfuric acid to produce an unknown quantity of potassium sulfate. All of the chemical substances involved in this reaction are compounds but in other examples the problem question 200 may comprise a chemical reaction that involves combinations of elements, molecules, ions and/or compounds.

[0031] The chemical reaction 204 may be presented on visual display 112 by the system 100 using a symbolic representation of the reaction 204 such as a chemical equation 206. The stoichiometric coefficients 208 of the chemical equation 206 may be left blank on the visual display 112 next to symbolic representations 210 of the chemical substances involved in the chemical equation 206. The problem question 200 may ask the student to calculate these coefficients by balancing the chemical equation 206 and to enter the values of the coefficients 208 into the relevant blank spaces using editable UI elements.

[0032] The problem question 200 may then ask the user to identify and extract each of the known physical quantities and the unknown physical quantities that the stoichiometric problem question 200 requires the student to calculate. The student may be asked to note the known and unknown physical quantities that they identify in separate boxes 212, 214 on the visual display 112.

[0033] A sequence of stoichiometric calculations 216 may be provided on the visual display 112 that have been determined in advance by the system 100. If and when the stoichiometric calculations 216 are performed correctly in sequential order by the student, this results in calculation of the relevant unknown physical quantity or quantities 214.

[0034] The first stoichiometric calculation 218 in the example sequence 216 requires the student to calculate the number of moles of potassium hydroxide involved in the chemical reaction 204 by dividing the mass of this compound by its molar mass. The mass of this compound is one of the known physical

quantities 212. The student may obtain the molar mass of the compound by referring to an appropriate external source of information. For example, the student may refer to a periodic table containing relative atomic mass information for each of the elements in the table. The student may then calculate the molar mass by summing together the respective relative atomic masses of the individual elements comprised in the compound.

[0035] Requiring the student to calculate the number of moles at the beginning of the sequence 216 advantageously simplifies the subsequent calculations that must be performed in the sequence 216. When moles is used as a base metric throughout the entire sequence 216, this advantageously provides for a structured and streamlined dissection of the stoichiometric problem question 200 into a series of comprehensible mathematical steps.

[0036] In the example depicted, the second stoichiometric calculation 220 in the sequence 216 then requires the student to use the result of the first stoichiometric calculation 218 to calculate the number of moles of potassium sulfate produced by the chemical reaction 204. The calculation 220 uses the ratio of stoichiometric coefficients 208 given in the balanced chemical equation 206 for, respectively, potassium hydroxide and potassium sulfate to achieve this.

[0037] The third stoichiometric calculation 222 in the sequence 216 requires the student to multiply the result of the second stoichiometric calculation 220 by the molar mass of potassium sulfate to calculate the mass of potassium sulfate produced by the chemical reaction 204. The final mass that is calculated 224 provides the single unknown physical quantity 224 that is required by the stoichiometric problem question 200.

[0038] It will be appreciated that one or more of the input parameters that must be provided to the stoichiometric calculations in the sequence 216 may comprise a numerical value that either (i) the problem question 200 provides to the student

or (ii) the student is required to calculate or derive in advance using information provided by the problem question 200. For example, an input parameter of the first stoichiometric calculation 218 in the sequence 216 comprises the mass of the potassium hydroxide (10.00 grammes). This numerical value is provided by the problem question 200 and comprises one of the known physical quantities 212. The first calculation 218 also has an input parameter that comprises the molar mass of potassium hydroxide. The student is required to derive the molar mass using the symbolic representation of this compound given in the problem question 200 (KOH) and a periodic table or similar suitable external source of information.

[0039] The second stoichiometric calculation 220 in the sequence 216 has an input parameter comprising the number of moles of potassium hydroxide calculated for the first stoichiometric calculation 218. The second calculation 220 also has input parameters that comprise stoichiometric coefficients of the balanced chemical equation 206 that the student was required to determine. The third and final stoichiometric calculation 222 in the sequence 216 has an input parameter comprising the number of moles of potassium sulfate, which is the result of the second stoichiometric calculation 220. The calculation 222 also has an input parameter comprising the molar mass of potassium sulfate. The student must calculate the molar mass by referring to the symbolic representation of this compound given in the problem question 200 ($K_2SO_4$) and a periodic table.

[0040] The sequence of stoichiometric calculations 216 are advantageously selected such that the student may clearly see how the stoichiometric problem question 200 can be divided into a plurality of sub-problems. Further, the student is able to appreciate that each of the sub-problems comprises a single stoichiometric calculation and that the sequence of calculations 216 incrementally lead the student from the initial problem through to the solution in a structured and easily comprehensible manner.

[0041] To further assist the student with identifying and understanding the interrelationships between the chain of stoichiometric calculations 216, a symbol or identifying mark that is unique in appearance and/or colour may be marked on the visual display 202 next to where dependent pairs of output values and input parameters are shown. For example, in Figure 2 the symbol 'm' is marked next to where the mass of potassium hydroxide is shown in the box of known physical quantities 212. This symbol is also shown next to the dividend of the division shown in the first stoichiometric calculation 218. The output value of the first stoichiometric calculation 218 is marked with the symbol 'x'. This symbol is also shown next to the dividend of the division shown in the second stoichiometric calculation 220. The output value of the second stoichiometric calculation 220 is marked with the symbol 'y'. This symbol is also shown next to the multiplicand of the multiplication shown in the third stoichiometric calculation 222.

[0042] The symbols or identifying marks serve as visual cues and enable the student to spot and understand the dependencies between the stoichiometric calculations in the sequence 216. In one example, the symbols or identifying marks may only be provided on the visual display 112 when the system 100 is being used to teach students who are new to stoichiometry. The symbols or identifying marks may not be marked on the visual display 112 for intermediate or advanced-level students.

[0043] Figure 3 depicts another example stoichiometric problem question 300 that may be presented to a student on a single screen 302 of the visual display 112 by the system 100. Similar to the example depicted in Figure 2, the question 300 comprises a chemical reaction 304, a chemical formulae 306 corresponding to the chemical reaction 304 that has blank stoichiometric coefficients 308 next to the relevant chemical symbols 310 of the formulae 306. The question 300 also comprises a pair of tables in which the student is required to record the known physical quantities 312 and the unknown physical quantities 314 required to be

calculated by the problem question 300 and a sequence of stoichiometric calculations 316. The first of the stoichiometric calculations 318 requires the student to calculate a number of moles of an amount of a compound that is involved in the chemical reaction 304. The final value 320 calculated when the stoichiometric calculations 310 have all been completed by the student correctly corresponds to the unknown physical quantity 314.

[0044] Figure 4 depicts another example stoichiometric problem question 400 that may be presented to a student on a single screen 402 the visual display 112 by the system 100. Similar to the examples depicted in Figures 2 and 3, the question 400 comprises a chemical transformation 404, a pair of tables in which the student is required to record the known physical quantities 406 and the unknown physical quantity or quantities 408 that are required to be calculated by the problem question 400 and a sequence of stoichiometric calculations 410. However, unlike the examples depicted in Figures 2 and 3, the problem question 400 does not comprise a chemical formula corresponding to a chemical reaction involved in the chemical transformation 404.

[0045] The first of the stoichiometric calculations 412 requires the student to calculate a number of moles of a change in amount of a compound that is involved in the chemical transformation 404. The final value 414 calculated when the stoichiometric calculations 410 have all been completed by the student correctly corresponds to the unknown physical quantity 408.

[0046] The website may be configured such that the numerical calculations are displayed on the visual display 112 all at the same time or in sequential order one by one. In the later example, for each individual calculation that has an earlier calculation immediately preceding the individual calculation in the sequence, the individual calculation is preferably only displayed on the visual display 112 after the user has submitted values for the relevant input parameters and output value of the earlier numerical calculation. Even more preferably, the

individual calculation is only displayed on the visual display 112 if the relevant values that are submitted by the user for the relevant input parameters and output value of the earlier numerical calculation are correct. This functionality advantageously forces the user to step through and attempt each of the calculations individually in the correct order.

[0047] The website may also provide that for each individual numerical calculation in the sequence, a range of possible values for the relevant input parameters and/or output value of the relevant individual calculation are displayed on the visual display 112 using suitable selectable UI controls, such as drop down menus. For each UI control, the user may only be permitted to select and submit one of the possible values provided in the relevant control to the website. When a value in the UI control is selected, the selected value may turn green if it is correct and red if it is incorrect. The website may also be implemented such that background information relating to one or more scientific theories or principles relevant to the numerical problem question is also displayed on the visual display 112.

[0048] The system 100 advantageously enables students to learn how to tackle and solve stoichiometry problem questions in a structured and user friendly format and engage in self-directed study.

[0049] For the purpose of this specification, the terms “stoichiometry” and “stoichiometric” refer to calculations that involve physical quantities of chemical substances in chemical and physical transformations, including reactants and products in chemical reactions. The term “physical quantity” refers to a quantified measurement of a physical property of a material or substance and includes both fundamental or base physical quantities, such as mass or temperature, and derived physical quantities, such as density, pressure or moles. The term “processor” refers to a device capable of executing instructions

encoding arithmetic, logical, and/or I/O operations and includes both a physical and a virtual processor. In one example, a processor may comprise an arithmetic logic unit, a control unit and a plurality of registers. In another example, a processor may comprise a single core processor capable of executing one instruction at a time (or process a single pipeline of instructions) or a multi-core processor which may simultaneously execute multiple instructions. The term “comprising” means “including but not limited to”, and the word "comprises" has a corresponding meaning.

[0050] The above embodiments have been described by way of example only and modifications are possible within the scope of the claims that follow.

**Claims**

1. A teaching system, comprising:

a server with at least one processor;

a network interface for communicatively connecting the server to at least one client device remote from the server over a computer network, wherein the client device comprises a visual display and a user input device; and

a web server executed by the processor of the server, wherein the web server hosts an interactive website that when accessed by the client device over the computer network causes the client device to:

render a chemistry-related numerical problem question on the visual display, wherein the problem question comprises one or more chemical substances, a chemical or physical transformation involving the chemical substances and one or more known physical quantities relating to the chemical substances and/or the chemical or physical transformation;

render one or more UI elements on the visual display, wherein the UI elements enable a user of the client device to identify and note the known physical quantities and at least one unknown physical quantity that is required to be calculated by the problem question;

receive and render on the visual display the known physical quantities and the unknown physical quantity noted by the user using the UI elements;

render a sequence of numerical calculations on the visual display, wherein the numerical calculations correspond to a sequence of numerical sub-problems that, when performed in sequential order by the user, result in a numerical value being calculated for the unknown physical quantity, wherein:

each of the numerical calculations transforms one or more input

parameters into an output value;

each of the input parameters comprises a quantity based or derived from one of the known physical quantities or an output value calculated for a previous numerical calculation in the sequence; and

at least one of the numerical calculations in the sequence comprises calculating a number of moles of an amount of, or a change in an amount of, at least one of the chemical substances due to the chemical or physical transformation;

receive, by the input device, user input submitted by the user that corresponds to the relevant input parameters and output value of each of the numerical calculations; and

render user feedback on the visual display, wherein the user feedback indicates whether or not the numerical value calculated by the user for the unknown physical quantity is correct.

2. The teaching system according to claim 1, wherein at least one of the numerical calculations in the sequence involves using a molar mass of a particular chemical substance in the chemical substances to calculate a number of moles of, or a change in an amount of, the particular chemical substance due to the chemical or physical transformation.

3. The teaching system according to claim 1 or 2, wherein:

the problem question further comprises a chemical reaction involving one or more of the chemical substances;

each of the chemical substances participating in the chemical reaction is an element, a molecule, an ion or a compound; and

one of more of the input parameters of the numerical calculations comprises a numerical value derived from one or more of the chemical substances participating in the chemical reaction.

4. The teaching system according to claim 3, wherein the client device is further caused to:

render a chemical equation on the visual display, wherein the chemical equation represents the chemical reaction;

render one or more UI elements on the visual display that require and allow the user to transform the chemical equation into a balanced chemical equation; and

render the sequence of numerical calculations on the visual display such that one of more of the input parameters comprises a stoichiometric coefficient of the balanced chemical equation.

5. The teaching system according to any one of the preceding claims, wherein:

the web server comprises data identifying a first numerical value that is provided, or that is required to be calculated, by the problem question, wherein the first numerical value is used as an input parameter of a second numerical calculation in the sequence;

the web server comprises data encoding a symbol or graphical marker that is unique in visual appearance; and

the client device is further caused to:

display a first instance of the symbol or graphical marker on the visual display at a position that is proximal to where the first numerical value is to be displayed on the visual display; and

display a second instance of the symbol or graphical marker on the visual display at a position that is proximal to where the second input parameter is to be displayed on the visual display, such that the first and second instances signify a relationship between the first numerical value and the second numerical calculation.

6. The teaching system according to claim 5, wherein the symbol or graphical marker has a unique colour.

7. The teaching system according to any one of the preceding claims, wherein the client device is further caused to:

display the numerical calculations on the visual display in sequential order one by one; and

for each individual numerical calculation in the sequence that has an earlier numerical calculation in the sequence immediately preceding the individual numerical calculation, only display the individual numerical calculation on the visual display after the user has submitted values for the relevant input parameters of the earlier numerical calculation.

8. The teaching system according to claim 7, wherein the client device is further caused to only display the individual numerical calculation on the visual display if the relevant values that are submitted by the user for the relevant input parameters of the earlier numerical calculation are correct.

9. The teaching system according to claim 7 or 8, wherein the client device is further caused to only display the individual numerical calculation on the visual display after the user has submitted a value for the relevant output value of the earlier numerical calculation.

10. The teaching system according to claim 9, wherein the individual numerical calculation is only displayed on the visual display if the relevant value that is submitted by the user for the relevant output parameter of the earlier numerical calculation is correct.

11. The teaching system according to any one of claims 7 to 10, wherein the client device is further caused to display a range of possible values for the

relevant input parameters and/or output value of the individual calculation on the visual display using selectable UI controls, wherein each of the selectable UI controls enables the user to select and submit to the website only one of the relevant possible values.

12. The teaching system according to claim 11, wherein the client device is further caused to display on the visual display a selected value submitted using one of the selectable UI controls in a unique colour, wherein the unique colour corresponds to whether the selected value is correct or incorrect.

13. The teaching system according to claim 12, wherein the unique colour is green if the selected value is correct and red if the selected value is incorrect.

14. The teaching system according to any one of claims 11 to 13, wherein each of the selectable UI controls comprises a drop down menu.

15. The teaching system according to any one of claims 1 to 6, wherein the client device is further caused to display all of the numerical calculations on the visual display at the same time, and wherein for each individual numerical calculation in the sequence:

a range of possible values for the relevant input parameters and/or output value of the relevant individual calculation are displayed on the visual display using selectable UI controls; and

for each of the selectable UI controls, the user may only select and submit to the website one of the possible values provided in the relevant selectable UI control.

16. The teaching system according to claim 15, wherein for each individual numerical calculation in the sequence that has an earlier numerical calculation in the sequence immediately preceding the relevant individual numerical

calculation, the user may not submit values for the relevant individual numerical calculation to the website unless and until the user has submitted values for the relevant input parameters of the earlier numerical calculation.

17. The teaching system according to any one of claims 8 to 17, wherein the client device is further caused to display on the visual display information relating to one or more scientific theories or principles relevant to the problem question.

18. A computer-readable non-transitory medium storing instructions that are executable by a web server hosted on a server, wherein the server comprises a network interface for communicatively connecting the server to at least one client device remote from the server over a computer network, and wherein the client device comprises a visual display and a user input device,
wherein the instructions, when executed by the web server, cause the client device to:

render a chemistry-related numerical problem question on the visual display, wherein the problem question comprises one or more chemical substances, a chemical or physical transformation involving the chemical substances and one or more known physical quantities relating to the chemical substances and/or the chemical or physical transformation;

render one or more UI elements on the visual display, wherein the UI elements enable a user of the client device to identify and note the known physical quantities and at least one unknown physical quantity that is required to be calculated by the problem question;

receive and render on the visual display the known physical quantities and the unknown physical quantity noted by the user using the UI elements;

render a sequence of numerical calculations on the visual display, wherein the numerical calculations correspond to a sequence of numerical sub-problems that, when performed in sequential order by the user, result in a numerical value being calculated for the unknown physical quantity, wherein:

each of the numerical calculations transforms one or more input parameters into an output value;

each of the input parameters comprises a quantity based or derived from one of the known physical quantities or an output value calculated for a previous numerical calculation in the sequence; and

at least one of the numerical calculations in the sequence comprises calculating a number of moles of an amount of, or a change in an amount of, at least one of the chemical substances due to the chemical or physical transformation;

receive, by the input device, user input submitted by the user that corresponds to the relevant input parameters and output value of each of the numerical calculations; and

render user feedback on the visual display, wherein the user feedback indicates whether or not the numerical value calculated by the user for the unknown physical quantity is correct.

24 Apr 2020
2020202767



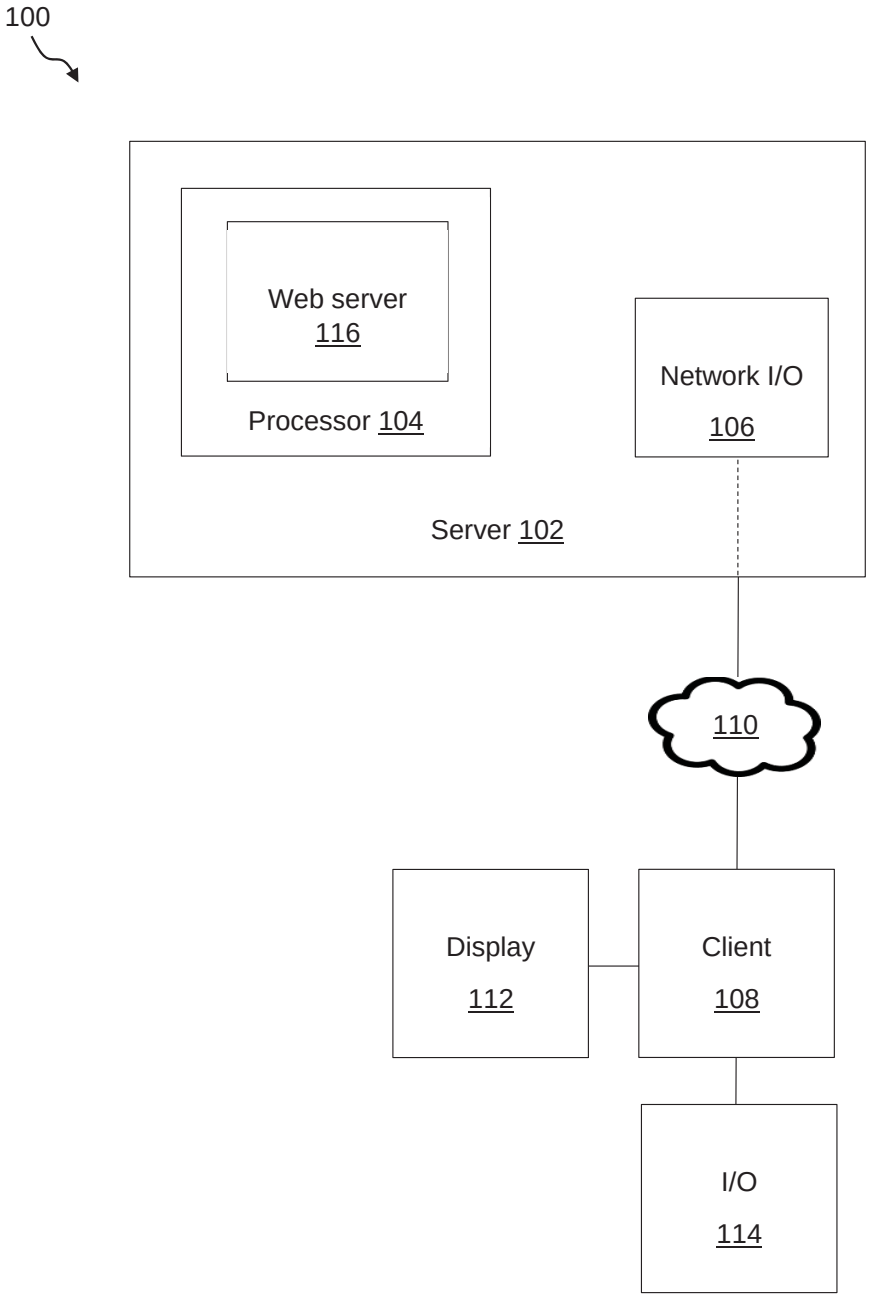


Figure 1

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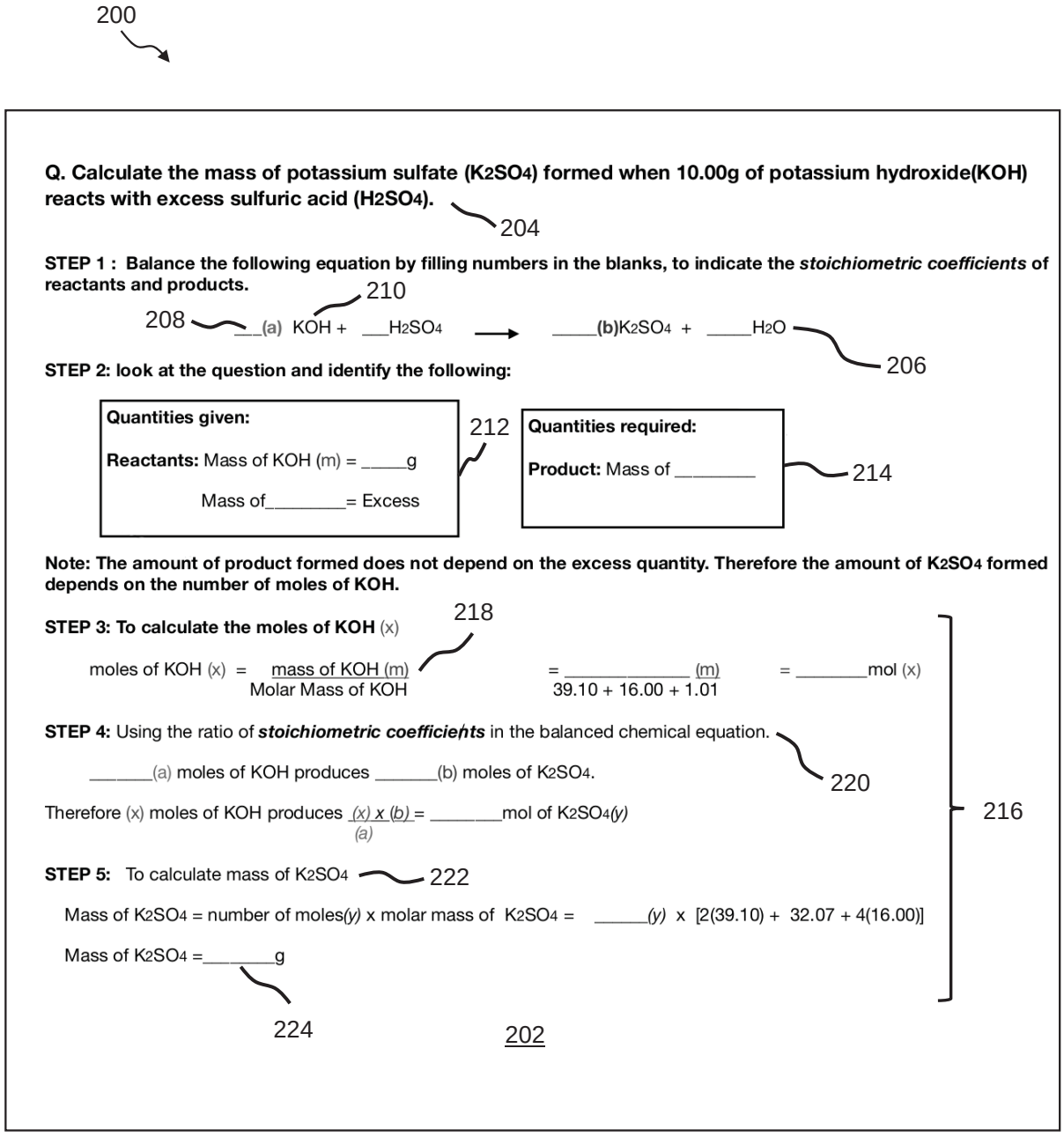


Figure 2

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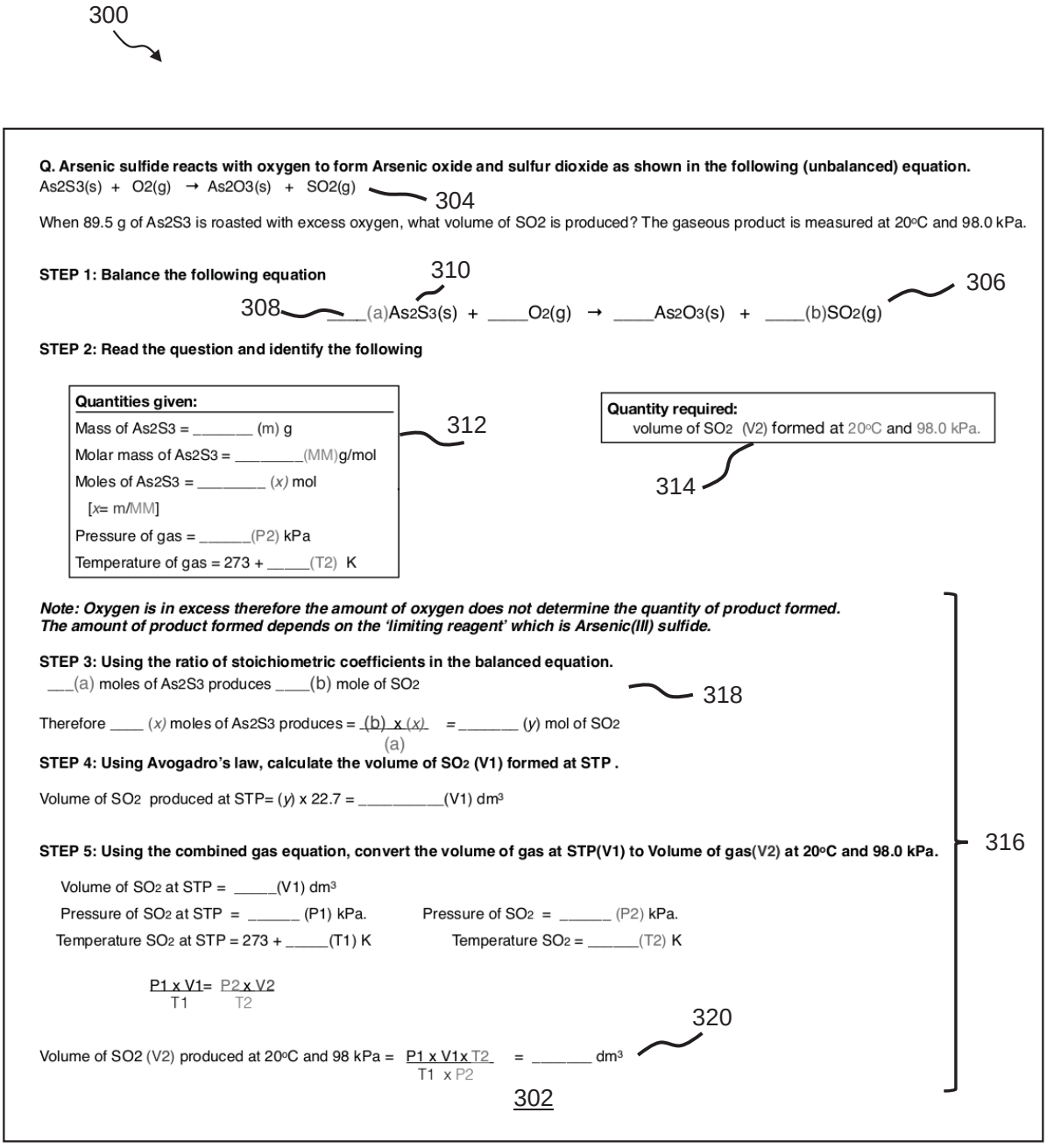


Figure 3

24 Apr 2020
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400

**Q. Calculate the enthalpy of combustion of ethanol when heat released on burning raises the temperature of 200g of water from 25°C to 33°C. Initial mass of spirit lamp with ethanol was 234.00g and final mass of was 233.55 g. Specific heat of water is 4.18 J/g/K.** 404

**Quantities given:** 406
Mass of water (m) = _____g
Initial Mass of ethanol(W1)= _____g
Final mass of ethanol(W2) = _____g
Initial temperature of water(T1) = _____°C
Final temperature of water(T2) = _____°C
Specific heat of water is 4.18 J/g/K

**Quantities required:** 408
Enthalpy of combustion($\Delta H^{\ominus}c$) of Ethanol

**STEP 1: To calculate the mass and moles of ethanol burnt.**

**W1 - W2 = _____(W) g is the the mass of fuel burnt**

Moles of ethanol burnt= $\frac{\text{_____W_____}}{\text{Molar Mass of ethanol}}$ = _____(x) mol 412

**STEP 2: To calculate the heat released when x mol of fuel is burnt and this heat is used to increase the temperature of water.**

Mass of water heated = _____m (g)
Change in temperature of water= T1-T2= -_____($\Delta T$) °C ($\Delta T$ will have a negative value)
Specific heat of water (s) = 4.18 J/g/K

Applying these 3 quantities to the calculate the heat released(q):

q= _____m x _____s x _____$\Delta T$ = _____J

*Note: Unit for $\Delta T$ must be considered in Kelvin scale (K) even though temperature is measured in °C because **difference** in temperature is used in the formula.*

**STEP 3: To calculate $\Delta H^{\ominus}c$ of fuel from 'q'**

$\Delta H^{\ominus}c = \frac{q}{x}$ = - _____J/mol Or - _____ KJ/mol 414

*Note: The answer will be a negative value which is correct because combustion is an exothermic process.*

410

402

Figure 4