The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Tuesday, June 23, 2015 — 9:15 a.m. to 12:15 p.m., only

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

This is a test of your knowledge of chemistry. Use that knowledge to answer all questions in this examination. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*. You are to answer *all* questions in all parts of this examination according to the directions provided in this examination booklet.

A separate answer sheet for Part A and Part B–1 has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers to the Part A and Part B–1 multiple-choice questions on this separate answer sheet. Record your answers for the questions in Part B–2 and Part C in your separate answer booklet. Be sure to fill in the heading on the front of your answer booklet.

All answers in your answer booklet should be written in pen, except for graphs and drawings, which should be done in pencil. You may use scrap paper to work out the answers to the questions, but be sure to record all your answers on your separate answer sheet or in your answer booklet as directed.

When you have completed the examination, you must sign the statement printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and answer booklet cannot be accepted if you fail to sign this declaration.

Notice. . .

A four-function or scientific calculator and a copy of the *2011 Edition Reference Tables for Physical Setting/Chemistry* must be available for you to use while taking this examination.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

1 Compared to an electron, which particle has a charge that is equal in magnitude but opposite in sign?

(1) an alpha particle (3) a neutron
(2) a beta particle (4) a proton

2 The mass of a proton is approximately equal to

(1) 1 atomic mass unit
(2) 12 atomic mass units
(3) the mass of 1 mole of carbon atoms
(4) the mass of 12 moles of electrons

3 Which property *decreases* when the elements in Group 17 are considered in order of increasing atomic number?

(1) atomic mass (3) melting point
(2) atomic radius (4) electronegativity

4 Any substance composed of two or more elements that are chemically combined in a fixed proportion is

(1) an isomer (3) a solution
(2) an isotope (4) a compound

5 Which term refers to how strongly an atom of an element attracts electrons in a chemical bond with an atom of a different element?

(1) entropy
(2) electronegativity
(3) activation energy
(4) first ionization energy

6 At STP, which substance has metallic bonding?

(1) ammonium chloride (3) iodine
(2) barium oxide (4) silver

7 What is the number of electrons shared between the carbon atoms in a molecule of ethyne?

(1) 6 (3) 8
(2) 2 (4) 4

8 Which atom in the ground state has a stable valence electron configuration?

(1) Ar (3) Si
(2) Al (4) Na

9 What occurs when two fluorine atoms react to produce a fluorine molecule?

(1) Energy is absorbed as a bond is broken.
(2) Energy is absorbed as a bond is formed.
(3) Energy is released as a bond is broken.
(4) Energy is released as a bond is formed.

10 Which gas sample at STP has the same number of molecules as a 2.0-liter sample of $Cl_2(g)$ at STP?

(1) 1.0 L of $NH_3(g)$ (3) 3.0 L of $CO_2(g)$
(2) 2.0 L of $CH_4(g)$ (4) 4.0 L of $NO(g)$

11 All atoms of uranium have the same

(1) mass number
(2) atomic number
(3) number of neutrons plus protons
(4) number of neutrons plus electrons

12 The concentration of a solution can be expressed in

(1) kelvins
(2) milliliters
(3) joules per kilogram
(4) moles per liter

13 Compared to the boiling point and the freezing point of water at 1 atmosphere, a 1.0 M $CaCl_2(aq)$ solution at 1 atmosphere has a

(1) lower boiling point and a lower freezing point
(2) lower boiling point and a higher freezing point
(3) higher boiling point and a lower freezing point
(4) higher boiling point and higher freezing point

14 According to the kinetic molecular theory, which statement describes an ideal gas?

(1) The gas particles are diatomic.
(2) Energy is created when the gas particles collide.
(3) There are no attractive forces between the gas particles.
(4) The distance between the gas particles is small, compared to their size.

15 Which physical change is endothermic?

(1) $CO_2(s) \rightarrow CO_2(g)$
(2) $CO_2(\ell) \rightarrow CO_2(s)$
(3) $CO_2(g) \rightarrow CO_2(\ell)$
(4) $CO_2(g) \rightarrow CO_2(s)$

16 Which Group 16 element combines with hydrogen to form a compound that has the strongest hydrogen bonding between its molecules?

(1) oxygen
(2) selenium
(3) sulfur
(4) tellurium

17 Hydrocarbons are composed of the elements

(1) carbon and hydrogen, only
(2) carbon and oxygen, only
(3) carbon, hydrogen, and oxygen
(4) carbon, nitrogen, and oxygen

18 Which atom is bonded to the carbon atom in the functional group of a ketone?

(1) fluorine
(2) hydrogen
(3) nitrogen
(4) oxygen

19 Two types of organic reactions are

(1) addition and sublimation
(2) deposition and saponification
(3) decomposition and evaporation
(4) esterification and polymerization

20 The isomers butane and methylpropane have

(1) the same molecular formula and the same properties
(2) the same molecular formula and different properties
(3) different molecular formulas and the same properties
(4) different molecular formulas and different properties

21 In a redox reaction, which particles are lost and gained in equal numbers?

(1) electrons
(2) neutrons
(3) hydroxide ions
(4) hydronium ions

22 What is the oxidation state for a Mn atom?

(1) 0
(2) +7
(3) +3
(4) +4

23 Which compounds are classified as electrolytes?

(1) KNO_3 and H_2SO_4
(2) KNO_3 and CH_3OH
(3) CH_3OCH_3 and H_2SO_4
(4) CH_3OCH_3 and CH_3OH

24 Which compound is an Arrhenius base?

(1) CO_2
(2) $CaSO_4$
(3) $Ca(OH)_2$
(4) C_2H_5OH

25 According to one acid-base theory, a water molecule acts as a base when it accepts

(1) an H^+ ion
(2) an OH^- ion
(3) a neutron
(4) an electron

26 Given the equation representing a system at equilibrium:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Which statement describes this reaction at equilibrium?

(1) The concentration of $N_2(g)$ decreases.
(2) The concentration of $N_2(g)$ is constant.
(3) The rate of the reverse reaction decreases.
(4) The rate of the reverse reaction increases.

27 The acidity or alkalinity of an unknown aqueous solution is indicated by its

(1) pH value
(2) electronegativity value
(3) percent by mass concentration
(4) percent by volume concentration

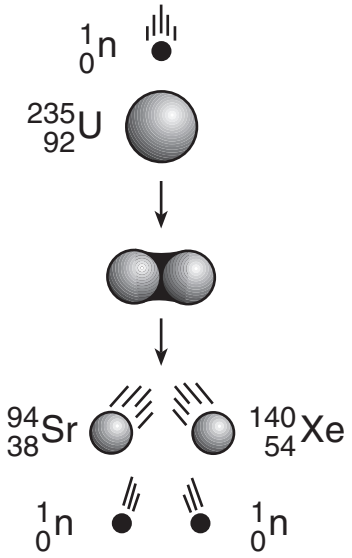
28 The laboratory process in which the volume of a solution of known concentration is used to determine the concentration of another solution is called

(1) distillation
(2) fermentation
(3) titration
(4) transmutation

29 Which list of nuclear emissions is arranged in order from the greatest penetrating power to the least penetrating power?

(1) alpha particle, beta particle, gamma ray
(2) alpha particle, gamma ray, beta particle
(3) gamma ray, alpha particle, beta particle
(4) gamma ray, beta particle, alpha particle

30 Given the diagram representing a reaction:



Which type of change is represented?

(1) fission
(2) fusion
(3) deposition
(4) evaporation

Part B–1

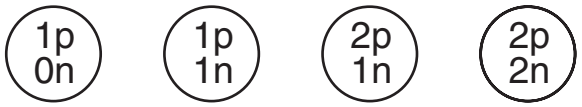
Answer all questions in this part.

Directions (31–50): For *each* statement or question, record on your separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

31 Which electron shell contains the valence electrons of a radium atom in the ground state?

(1) the sixth shell
(2) the second shell
(3) the seventh shell
(4) the eighteenth shell

32 Each diagram below represents the nucleus of an atom.



How many different elements are represented by the diagrams?

(1) 1
(2) 2
(3) 3
(4) 4

33 Chlorine and element *X* have similar chemical properties. An atom of element *X* could have an electron configuration of

(1) 2-2
(2) 2-8-1
(3) 2-8-8
(4) 2-8-18-7

34 Which group of elements contains a metalloid?

(1) Group 8
(2) Group 2
(3) Group 16
(4) Group 18

35 Which Lewis electron-dot diagram represents a fluoride ion?

(1) (2) (3) (4)

36 In the formula for the compound XCl_4, the *X* could represent

(1) C
(2) H
(3) Mg
(4) Zn

37 The formula C_2H_4 can be classified as

(1) a structural formula, only
(2) a molecular formula, only
(3) both a structural formula and an empirical formula
(4) both a molecular formula and an empirical formula

38 Given the balanced equation representing a reaction:

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

How many moles of Al(s) react completely with 4.50 moles of $O_2(g)$ to produce 3.00 moles of $Al_2O_3(s)$?

(1) 1.50 mol
(2) 2.00 mol
(3) 6.00 mol
(4) 4.00 mol

39 What is the percent composition by mass of oxygen in $Ca(NO_3)_2$ (gram-formula mass = 164 g/mol)?

(1) 9.8%
(2) 29%
(3) 48%
(4) 59%

40 Given the balanced equation representing a reaction:

$$6Li + N_2 \rightarrow 2Li_3N$$

Which type of chemical reaction is represented by this equation?

(1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

41 Which elements can react to produce a molecular compound?

(1) calcium and chlorine
(2) hydrogen and sulfur
(3) lithium and fluorine
(4) magnesium and oxygen

42 Compared to a 1.0-mole sample of NaCl(s), a 1.0-mole sample of NaCl(ℓ) has a *different*

(1) number of ions
(2) empirical formula
(3) gram-formula mass
(4) electrical conductivity

43 Which property of an unsaturated solution of sodium chloride in water remains the same when more water is added to the solution?

(1) density of the solution
(2) boiling point of the solution
(3) mass of sodium chloride in the solution
(4) percent by mass of water in the solution

44 Which ion combines with Ba^{2+} to form a compound that is most soluble in water?

(1) S^{2-}
(2) OH^-
(3) CO_3^{2-}
(4) SO_4^{2-}

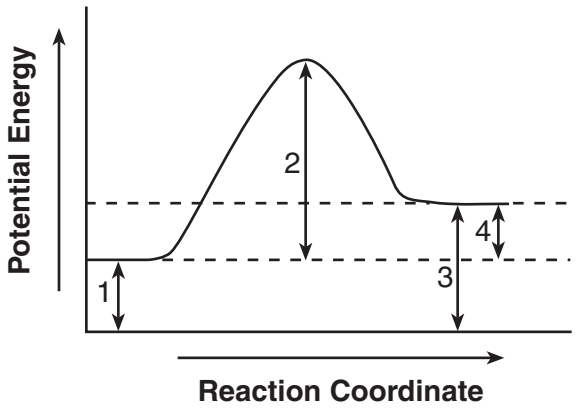
45 When a sample of gas is cooled in a sealed, rigid container, the pressure the gas exerts on the walls of the container will decrease because the gas particles hit the walls of the container

(1) less often and with less force
(2) less often and with more force
(3) more often and with less force
(4) more often and with more force

46 A rigid cylinder with a movable piston contains 50.0 liters of a gas at 30.0°C with a pressure of 1.00 atmosphere. What is the volume of the gas in the cylinder at STP?

(1) 5.49 L
(2) 45.0 L
(3) 55.5 L
(4) 455 L

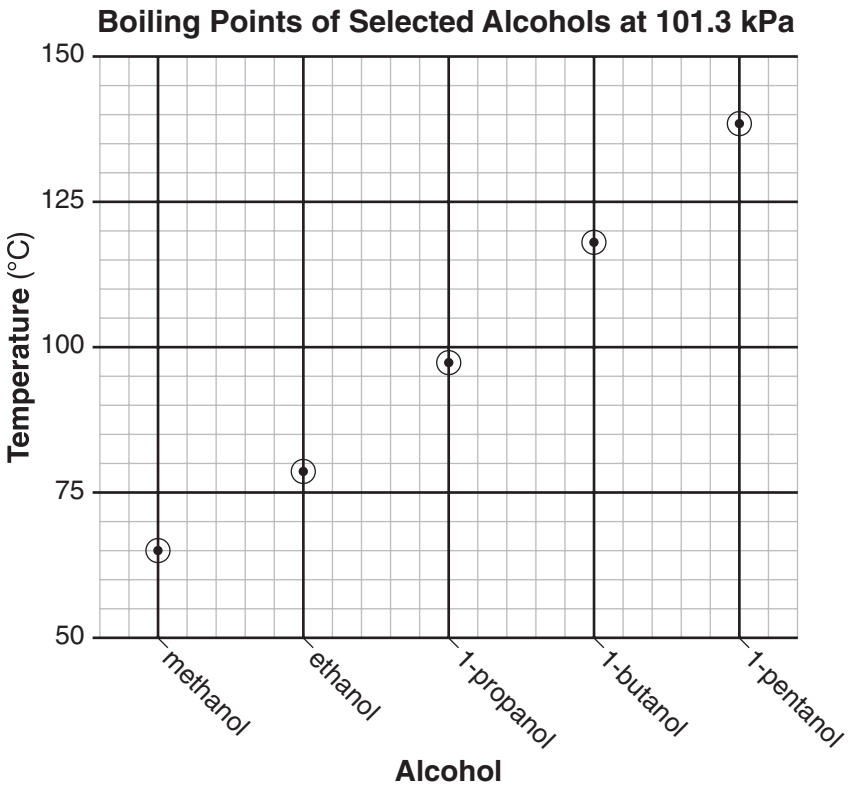
47 Given the potential energy diagram for a chemical reaction:



Which numbered interval represents the heat of reaction?

(1) 1
(2) 2
(3) 3
(4) 4

Base your answers to questions 48 and 49 on the graph below and on your knowledge of chemistry.



48 What is represented by the number "1" in the IUPAC name for three of these alcohols?

(1) the number of isomers for each alcohol
(2) the number of −OH groups for each carbon atom in each alcohol molecule
(3) the location of an −OH group on one end of the carbon chain in each alcohol molecule
(4) the location of an −OH group in the middle of the carbon chain in each alcohol molecule

49 What can be concluded from this graph?

(1) At 101.3 kPa, water has a higher boiling point than 1-butanol.
(2) At 101.3 kPa, water has a lower boiling point than ethanol.
(3) The greater the number of carbon atoms per alcohol molecule, the lower the boiling point of the alcohol.
(4) The greater the number of carbon atoms per alcohol molecule, the higher the boiling point of the alcohol.

50 In the laboratory, a student investigates the effect of concentration on the reaction between HCl(aq) and Mg(s), changing only the concentration of HCl(aq). Data for two trials in the investigation are shown in the table below.

Data Table

Trial	Volume of HCl(aq) (mL)	Concentration of HCl(aq) (M)	Mass of Mg(s) (g)	Reaction Time (s)
1	50.0	0.2	0.1	48
2	50.0	0.4	0.1	?

Compared to trial 1, what is the expected reaction time for trial 2 and the explanation for that result?

(1) less than 48 s, because there are fewer effective particle collisions per second
(2) less than 48 s, because there are more effective particle collisions per second
(3) more than 48 s, because there are fewer effective particle collisions per second
(4) more than 48 s, because there are more effective particle collisions per second

Part B–2

Answer all questions in this part.

Directions (51–65): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry.*

51 Determine the volume of 2.00 M HCl(aq) solution required to completely neutralize 20.0 milliliters of 1.00 M NaOH(aq) solution. [1]

52 Determine the mass of KNO_3 that dissolves in 100. grams of water at 40.°C to produce a saturated solution. [1]

53 State, in terms of molecular polarity, why ethanol is soluble in water. [1]

Base your answers to questions 54 through 56 on the information below and on your knowledge of chemistry.

Three elements, represented by *D*, *E*, and *Q*, are located in Period 3. Some properties of these elements are listed in the table below. A student's experimental result indicates that the density of element *Q* is 2.10 g/cm^3, at room temperature and standard pressure.

Properties of Samples of Three Elements at Room Temperature and Standard Pressure

Element	Phase	Mass (g)	Density (g/cm^3)	Oxide Formula
D	solid	50.0	0.97	D_2O
E	solid	50.0	1.74	EO
Q	solid	50.0	2.00	QO_2 *or* QO_3

54 Identify the physical property in the table that could be used to differentiate the samples of the three elements from each other. [1]

55 Identify the group on the Periodic Table to which element *D* belongs. [1]

56 Determine the percent error between the student's experimental density and the accepted density of element *Q*. [1]

Base your answers to questions 57 through 59 on the information below and on your knowledge of chemistry.

The equation below represents an equilibrium system of $SO_2(g)$, $O_2(g)$, and $SO_3(g)$. The reaction can be catalyzed by vanadium or platinum.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + \text{energy}$$

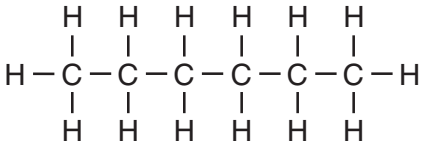
57 Compare the rates of the forward and reverse reactions at equilibrium. [1]

58 State how the equilibrium shifts when $SO_3(g)$ is removed from the system. [1]

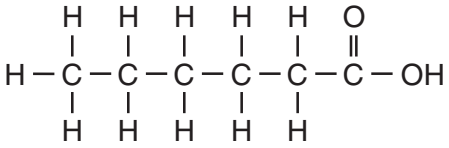
59 A potential energy diagram for the forward reaction is shown *in your answer booklet.* On this diagram, draw a dashed line to show how the potential energy changes when the reaction occurs by the catalyzed pathway. [1]

Base your answers to questions 60 and 61 on the information below and on your knowledge of chemistry.

The formulas for two compounds are shown below.



Compound A



Compound B

60 Explain, in terms of bonding, why compound *A* is saturated. [1]

61 Explain, in terms of molecular structure, why the chemical properties of compound *A* are different from the chemical properties of compound *B*. [1]

Base your answers to questions 62 through 65 on the information below and on your knowledge of chemistry.

Some isotopes of potassium are K-37, K-39, K-40, K-41, and K-42. The natural abundance and the atomic mass for the naturally occurring isotopes of potassium are shown in the table below.

Naturally Occurring Isotopes of Potassium

Isotope Notation	**Natural Abundance** (%)	**Atomic Mass** (u)
K-39	93.26	38.96
K-40	0.01	39.96
K-41	6.73	40.96

62 Identify the decay mode of K-37. [1]

63 Complete the nuclear equation *in your answer booklet* for the decay of K-40 by writing a notation for the missing nuclide. [1]

64 Determine the fraction of an original sample of K-42 that remains unchanged after 24.72 hours. [1]

65 Show a numerical setup for calculating the atomic mass of potassium. [1]

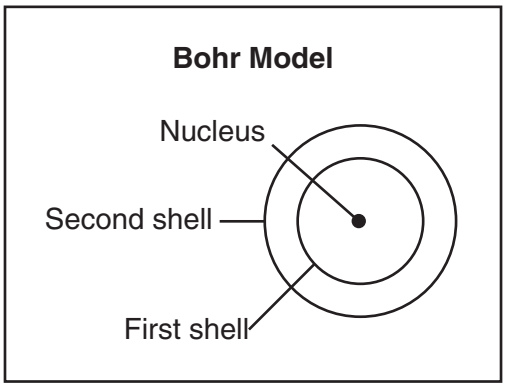
Part C

Answer all questions in this part.

Directions (66–85): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2011 Edition Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 66 through 68 on the information below and on your knowledge of chemistry.

The Bohr model of the atom was developed in the early part of the twentieth century. A diagram of the Bohr model for one atom, in the ground state, of a specific element is shown below. The nucleus of this atom contains 4 protons and 5 neutrons.



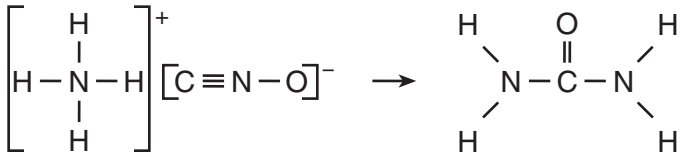
66 State the atomic number and the mass number of this element. [1]

67 State the number of electrons in *each* shell in this atom in the ground state. [1]

68 Using the Bohr model, describe the changes in electron energy and electron location when an atom changes from the ground state to an excited state. [1]

Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

In 1828, Friedrich Wöhler produced urea when he heated a solution of ammonium cyanate. This reaction is represented by the balanced equation below.



Ammonium cyanate

Urea

69 Identify the element in urea that makes it an organic compound. [1]

70 Determine the gram-formula mass of the product. [1]

71 Write an empirical formula for the product. [1]

72 Explain why this balanced equation represents a conservation of atoms. [1]

Base your answers to questions 73 through 75 on the information below and on your knowledge of chemistry.

Rubbing alcohol sold in stores is aqueous 2-propanol, $CH_3CHOHCH_3(aq)$. Rubbing alcohol is available in concentrations of 70.% and 91% 2-propanol by volume.

To make 100. mL of 70.% aqueous 2-propanol, 70. mL of 2-propanol is diluted with enough water to produce a total volume of 100. mL. In a laboratory investigation, a student is given a 132-mL sample of 91% aqueous 2-propanol to separate using the process of distillation.

73 State evidence that indicates the proportions of the components in rubbing alcohol can vary. [1]

74 Identify the property of the components that makes it possible to use distillation to separate the 2-propanol from water. [1]

75 Determine the maximum volume of 2-propanol in the 132-mL sample. [1]

Base your answers to questions 76 through 79 on the information below and on your knowledge of chemistry.

A sample of seawater is analyzed. The table below gives the concentration of some ions in the sample.

Concentration of Some Ions in a Seawater Sample

Ion	**Concentration** (M)
Cl^-	0.545
Na^+	0.468
Mg^{2+}	0.054
SO_4^{2-}	0.028
Ca^{2+}	0.010
K^+	0.010

76 Write a chemical formula of *one* compound formed by the combination of K^+ ions with one of these ions as water completely evaporates from the seawater sample. [1]

77 Determine the number of moles of the SO_4^{2-} ion in a 1400.-liter sample of the seawater. [1]

78 Compare the radius of an Mg^{2+} ion in the seawater to the radius of an Mg atom. [1]

79 Using the key *in your answer booklet*, draw *two* water molecules in the box, showing the orientation of *each* water molecule toward the calcium ion. [1]

Base your answers to questions 80 through 82 on the information below and on your knowledge of chemistry.

A scientist bubbled HCl(g) through a sample of $H_2O(\ell)$. This process is represented by the balanced equation below.

$$H_2O(\ell) + HCl(g) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

The scientist measured the pH of the liquid in the flask before and after the gas was bubbled through the water. The initial pH value of the water was 7.0 and the final pH value of the solution was 3.0.

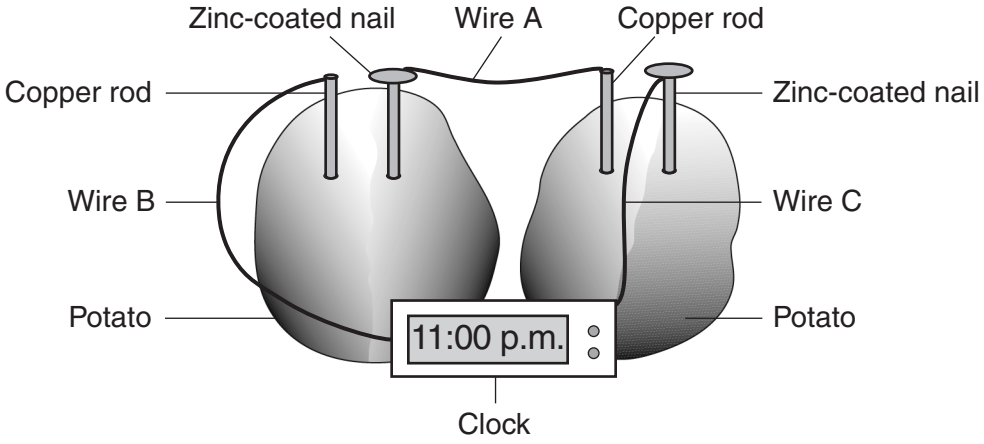
80 Explain, in terms of ions, why the gaseous reactant in the equation is classified as an Arrhenius acid. [1]

81 What would be the color of bromcresol green if it had been added to the water in the flask before any of the HCl(g) was bubbled through the water? [1]

82 Compare the hydronium ion concentration of the solution that has the pH value of 3.0 to the hydronium ion concentration of the water. [1]

Base your answers to questions 83 through 85 on the information below and on your knowledge of chemistry.

A small digital clock can be powered by a battery made from two potatoes and some household materials. The "potato clock" battery consists of two cells connected in a way to produce enough electricity to allow the clock to operate. In each cell, zinc atoms react to form zinc ions. Hydrogen ions from phosphoric acid in the potatoes react to form hydrogen gas. The labeled diagram and balanced ionic equation below show the reaction, the materials, and connections necessary to make a "potato clock" battery.



$$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$$

83 State the direction of electron flow in wire *A* as the two cells operate. [1]

84 Write a balanced half-reaction equation for the oxidation that occurs in the "potato clock" battery. [1]

85 Explain why phosphoric acid is needed for the battery to operate. [1]

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