The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, August 17, 2023 — 8:30 to 11:30 a.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 Which proposal in the development of the modern model of the atom was made before the others?
  (1) Atoms are hard, indivisible spheres of different sizes.
  (2) Atoms are mostly empty space with a small dense nucleus.
  (3) Atoms have electrons that have wavelike properties.
  (4) Atoms have an internal structure that contains negative particles.

2 According to the wave-mechanical model, in the ground state, the 10 electrons of a neon atom would be located
  (1) in the nucleus   (3) in the first shell
  (2) in orbitals   (4) in the valence shell

3 Which statement describes two different isotopes of carbon?
  (1) The isotopes contain the same number of neutrons and have the same atomic number.
  (2) The isotopes contain the same number of neutrons but have a different atomic number.
  (3) The isotopes contain a different number of neutrons but have the same atomic number.
  (4) The isotopes contain a different number of neutrons and have a different atomic number.

4 An element that is a very reactive metal could have an atomic number of
  (1) 9   (3) 19
  (2) 2   (4) 79

5 Which element is listed with the number of protons in each of its atoms?
  (1) nitrogen, 14   (3) oxygen, 16
  (2) silicon, 14   (4) phosphorus, 16

6 What is the overall charge on the nucleus of a fluorine atom?
  (1) -1 (3) $+9$
  (2) -9 (4) $+19$

7 As the elements with atomic numbers 11 through 17 are considered in order of increasing atomic number, the classification of the elements changes from
  (1) metal to metalloid to nonmetal
  (2) metal to nonmetal to metalloid
  (3) nonmetal to metalloid to metal
  (4) nonmetal to metal to metalloid

8 At STP, which property can be used to differentiate one-mole samples of $Cl_2(g)$ and $Kr(g)$?
  (1) phase   (3) chemical reactivity
  (2) pressure   (4) temperature

9 Two gaseous forms of oxygen are diatomic oxygen, O_2, and ozone, O_3. These two forms of oxygen have
  (1) the same molecular structure and the same properties
  (2) the same molecular structure and different properties
  (3) different molecular structures and the same properties
  (4) different molecular structures and different properties

10 A compound consists of two or more different elements that are
  (1) physically mixed in a fixed proportion
  (2) physically mixed in a proportion that can vary
  (3) chemically combined in a fixed proportion
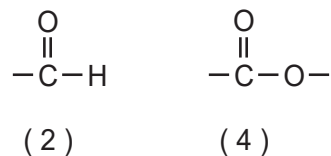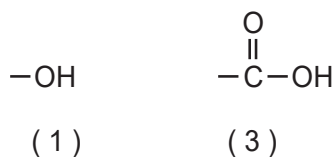 (4) chemically combined in a proportion that can vary

11 Compared to the chemical and physical properties of the compound CO, the compound CO_2 has

(1) the same chemical properties and the same physical properties
(2) the same chemical properties and different physical properties
(3) different chemical properties and the same physical properties
(4) different chemical properties and different physical properties

12 Which phrase describes the molecular polarity of and the charge distribution in an HCl molecule?

(1) nonpolar with an asymmetrical charge distribution
(2) nonpolar with a symmetrical charge distribution
(3) polar with an asymmetrical charge distribution
(4) polar with a symmetrical charge distribution

13 Which atom forms an ion with a radius larger than the atomic radius?

(1) calcium atom   (3) lead atom
(2) oxygen atom   (4) tin atom

14 Which sample can be classified as a substance?

(1) air   (3) soil
(2) argon   (4) seawater

15 A 1.0-gram sample of NaCl(s) is dissolved in 100. grams of water at 25°C, and another 1.0-gram sample of NaCl(s) is dissolved in 50. grams of water at 25°C. Which property of the two resulting mixtures will be different?

(1) color of the components in the mixture
(2) particle size of the components in the mixture
(3) polarity of the components in the mixture
(4) proportion by mass of the components in the mixture

16 Based on Table G, which compound has the greatest solubility in 100. grams of water at 10.°C?

(1) HCl   (3) KCl
(2) NaCl   (4) NH_4Cl

17 According to the kinetic molecular theory, ideal gas particles

(1) are separated by small distances relative to their size
(2) do not transfer energy when they collide with each other
(3) have attractive forces between them
(4) move in random, constant, straight-line motion

18 A reaction is most likely to occur when the reacting particles collide with proper orientation and proper

(1) charge   (3) mass
(2) energy   (4) volume

19 A sample of $SO_2(g)$ and a sample of $NO_2(g)$ contain the same number of molecules when they have the same

(1) mass, temperature, and volume
(2) mass, temperature, and pressure
(3) pressure, volume, and temperature
(4) pressure, volume, and mass

20 Which term identifies the strong intermolecular forces found in a sample of liquid water?

(1) ionic bonding   (3) hydrogen bonding
(2) covalent bonding   (4) metallic bonding

21 Which mathematical expression represents the heat of reaction for a chemical change?

(1) (PE of the products) − (PE of the reactants)
(2) (PE of the products) + (PE of the reactants)
(3) (PE of the products) ÷ (PE of the reactants)
(4) (PE of the products) × (PE of the reactants)

22 Catalysts can increase the rate of a chemical reaction by providing

(1) an alternate reaction pathway with a higher activation energy
(2) the same reaction pathway with a higher activation energy
(3) an alternate reaction pathway with a lower activation energy
(4) the same reaction pathway with a lower activation energy

23 Which term represents the disorder of a system?

(1) entropy   (3) quanta
(2) mole   (4) pressure

24 Which element must be present in all organic compounds?

(1) nitrogen   (3) carbon
(2) hydrogen   (4) sulfur

25 Based on Table R, which functional group allows a compound to be classified as an organic acid?

$$-OH$$

(1)

$$\begin{array}{c} O \\ \| \\ -C-OH \end{array}$$

(3)

$$\begin{array}{c} O \\ \| \\ -C-H \end{array}$$

(2)

$$\begin{array}{c} O \\ \| \\ -C-O- \end{array}$$

(4)

26 In a voltaic cell, oxidation occurs

(1) at the cathode
(2) at the anode
(3) in the salt bridge
(4) in the external circuit

27 Which positive ion must be present in an aqueous solution of an Arrhenius acid?

(1) H_3O^+ (3) NH_4^+
(2) Na^+ (4) Rb^+

28 A change that converts an atom of one element to another element is called

(1) neutralization   (3) sublimation
(2) oxidation   (4) transmutation

29 Which radiation has the *least* ionizing power and greatest penetrating power?

(1) alpha particles (3) gamma emissions
(2) beta particles   (4) positron emissions

30 Which nuclear emission is listed with its notation?

(1) alpha particle, ^1_1p (3) neutron, $^0_0\gamma$
(2) beta particle, $^0_{-1}e$ (4) proton, $^0_{+1}\beta$

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 Diagram 1 represents an atom of hydrogen, showing the nucleus and the electron in the first shell.

Diagram 1

Nucleus

e⁻

Diagram 2

Nucleus

e⁻
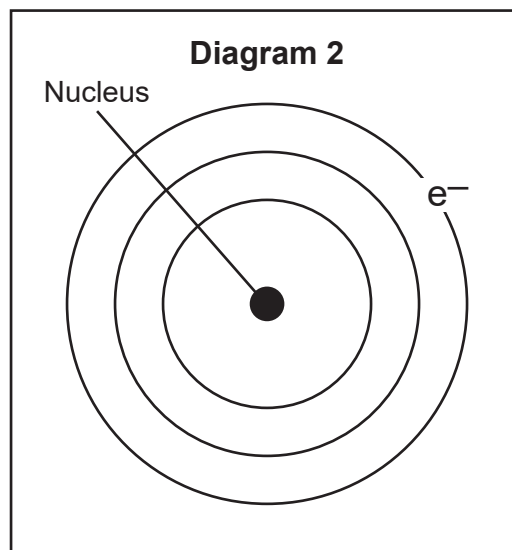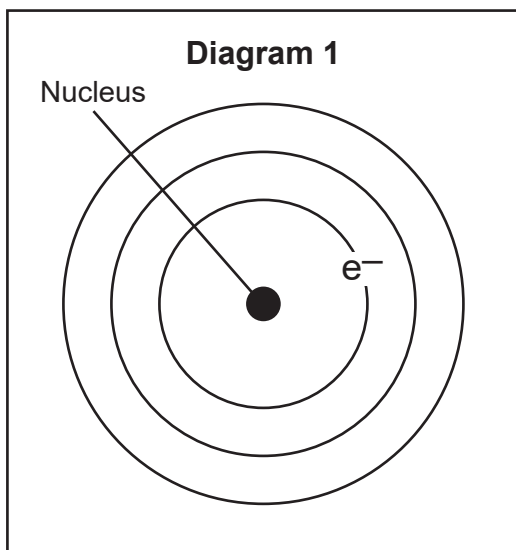
What is represented by diagram 2?

(1) a positive ion of hydrogen
(2) a negative ion of hydrogen
(3) an atom of hydrogen in an excited state
(4) an atom of hydrogen in the ground state

32 The table below gives the atomic mass and the abundance of the two naturally occurring isotopes of copper.

Naturally Occurring Isotopes of Copper

Isotope Notation	Atomic Mass of the Isotope (u)	Natural Abundance (%)
Cu-63	62.93	69.15
Cu-65	64.93	30.85

Which numerical setup can be used to calculate the atomic mass of the element copper?

(1) (62.93 u)(30.85) + (64.93 u)(69.15)
(2) (62.93 u)(69.15) + (64.93 u)(30.85)
(3) (62.93 u)(0.3085) + (64.93 u)(0.6915)
(4) (62.93 u)(0.6915) + (64.93 u)(0.3085)

33 Which subatomic particles were discovered as the result of experiments with cathode ray tubes?

(1) electrons (3) positrons
(2) neutrons (4) protons

34 Which change in electron location in an atom of calcium is accompanied by the greatest amount of energy emitted?

(1) from shell 1 to shell 2
(2) from shell 2 to shell 1
(3) from shell 1 to shell 4
(4) from shell 4 to shell 1

35 As the atomic number increases in Group 2 from Be to Ba, the first ionization energy

(1) decreases, and the atomic radius decreases
(2) decreases, and the atomic radius increases
(3) increases, and the atomic radius decreases
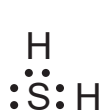(4) increases, and the atomic radius increases

36 Given the equation representing a reaction:

$$3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$$
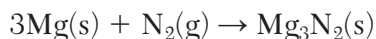
What is the mass of Mg_3N_2 that is produced when 14.58 grams of magnesium completely reacts with 5.60 grams of nitrogen?
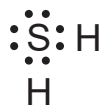
(1) 8.98 g (3) 20.18 g
(2) 10.46 g (4) 49.34 g

37 Which Lewis electron-dot diagram represents a molecule of H_2S?

H
:S:H

(1)

H
·H:S:

(3)

:S:H
H

(2)

·H:S:
H

(4)

38 What is the vapor pressure of water at 90.°C?

(1) 40. kPa (3) 94 kPa
(2) 68 kPa (4) 150. kPa

39 A sample is composed of two different substances that can be separated by using filter paper. This sample is classified as

(1) a heterogeneous mixture
(2) a homogeneous mixture
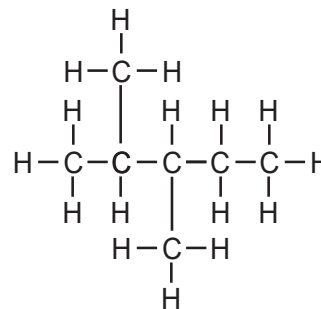(3) a single compound
(4) an unsaturated solution

40 Which solutions react to produce an insoluble compound?

(1) $KCl(aq) + LiCl(aq) \rightarrow$
(2) $LiCl(aq) + NaNO_3 (aq) \rightarrow$
(3) $NaCl (aq) + AgClO_3 (aq) \rightarrow$
(4) $KNO_3 (aq) + AgClO_3(aq) \rightarrow$

41 What is the amount of heat energy absorbed when 40.0 grams of water is heated from 10.0°C to 30.0°C?

(1) 1.67×10^3 J (3) 5.02×10^3 J
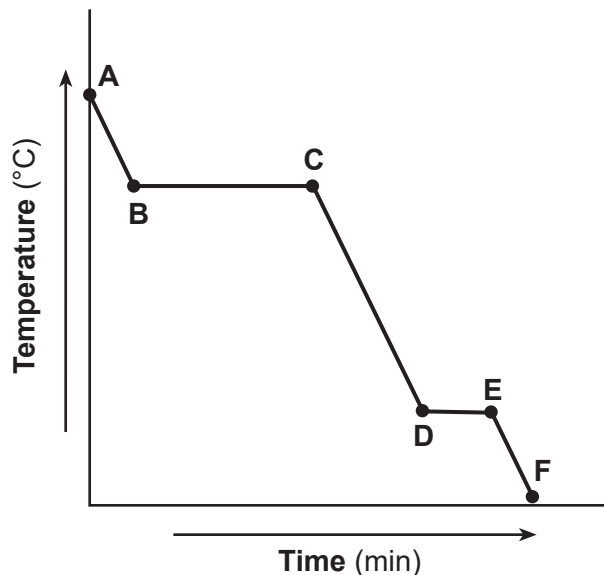(2) 3.34×10^3 J (4) 2.67×10^5 J

42 Given the formula representing a compound:

What is a chemical name of this compound?

(1) 2,3,3-trimethylbutane
(2) 2-methyl-2-ethylbutane
(3) 2,3-dimethylpentane
(4) 2,3-ethylpentane

43 Given the cooling curve for a substance:

During which intervals is the potential energy decreasing while the average kinetic energy remains constant?

(1) BC and AB (3) EF and AB
(2) BC and DE (4) EF and DE

44 Which formula represents a hydrocarbon?

(1) CO_2 (3) $C_2H_4O_2$
(2) C_3H_8 (4) C_3H_8O

45 Which type of organic reaction produces carbon dioxide and water?

(1) combustion   (3) fermentation
(2) esterification   (4) saponification

46 Which half-reaction equation represents the oxidation of lithium?

(1) $Li^+ + e^- \rightarrow Li$ (3) $Li \rightarrow Li + e^-$
(2) $Li + e^- \rightarrow Li^+$ (4) $Li \rightarrow Li^+ + e^-$

47 Based on Table J, which ionic equation represents a spontaneous reaction that can occur in a voltaic cell?

(1) $Fe(s) + Mg^{2+}(aq) \rightarrow Fe^{2+}(aq) + Mg(s)$
(2) $Fe(s) + Mg(s) \rightarrow Fe^{2+}(aq) + Mg^{2+}(aq)$
(3) $Fe^{2+}(aq) + Mg^{2+}(aq) \rightarrow Fe(s) + Mg(s)$
(4) $Fe^{2+}(aq) + Mg(s) \rightarrow Fe(s) + Mg^{2+}(aq)$

48 Given the equation representing a system at equilibrium:

$$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

In this system, the $H_2O(\ell)$ acts as

(1) an acid, because it accepts an H^+
(2) an acid, because it donates an H^+
(3) a base, because it accepts an H^+
(4) a base, because it donates an H^+

49 Which indicator is blue in a solution that has a pH value of 7.0?

(1) bromcresol green   (3) phenolphthalein
(2) methyl orange   (4) thymol blue

50 Which radioisotope requires long-term storage to prevent the risk of biological exposure?

(1) N-16   (3) Pu-239
(2) K-42   (4) Au-198

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*.

Base your answers to questions 51 and 52 on the information below and on your knowledge of chemistry.

The four naturally occurring isotopes of sulfur are sulfur-32, sulfur-33, sulfur-34, and sulfur-36.

51 State the number of valence electrons in an atom of sulfur-32 in the ground state.   [1]

52 State the number of neutrons in an atom of sulfur-33.   [1]

Base your answers to questions 53 through 55 on the information below and on your knowledge of chemistry.

The Group 1 elements below hydrogen are called alkali metals, and the first five Group 17 elements are called halogens.

53 Compare the electrical conductivity of an alkali metal at STP with the electrical conductivity of a halogen at STP.   [1]

54 State the type of chemical bonds formed when an alkali metal and a halogen react to form a compound.   [1]

55 Explain, in terms of electrons, why the halogens are all placed in the same group on the Periodic Table.   [1]

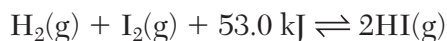Base your answers to questions 56 through 58 on the information below and on your knowledge of chemistry.

The unbalanced equation below represents the reaction between silver sulfide and aluminum.

$$Ag_2S + Al \rightarrow Ag + Al_2S_3$$
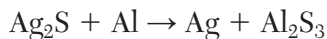
56 Balance the equation *in your answer booklet* for the reaction, using the *smallest* whole number coefficients. [1]

57 Determine the gram-formula mass of the aluminum sulfide product. [1]

58 Show a numerical setup for calculating the number of moles of silver sulfide in a 546-gram sample of Ag_2S (gram-formula mass = 248 g/mol). [1]

___

Base your answers to questions 59 through 61 on the information below and on your knowledge of chemistry.

Hydrogen gas and iodine gas can combine in a reversible reaction to form hydrogen iodide gas. The equation below represents this system at equilibrium in a sealed, rigid container.

$$H_2(g) + I_2(g) + 53.0 \text{ kJ} \rightleftharpoons 2HI(g)$$

59 State evidence from the equation that the forward reaction is endothermic. [1]

60 State, in terms of reaction rates, why the concentration of $HI(g)$ remains constant when the system is at equilibrium. [1]

61 State how an increase in temperature affects the concentration of $HI(g)$. [1]

___

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

The equation below represents the reaction of straight-chain butane with chlorine.

$$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$$
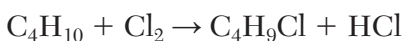
The reaction produces two different isomers of C_4H_9Cl: 1-chlorobutane and 2-chlorobutane. The table below shows the boiling point of each C_4H_9Cl isomer at standard pressure.

Name of Compound	Boiling Point (°C)
1-chlorobutane	78.4
2-chlorobutane	68.2

62 State, in terms of carbon-carbon bonds, why butane is saturated. [1]

63 Identify the class of organic compounds to which the organic product in the equation belongs. [1]

64 Based on the boiling point data, compare the strength of the intermolecular forces in 1-chlorobutane to the strength of the intermolecular forces in 2-chlorobutane. [1]

65 Draw a structural formula for the 2-chlorobutane. [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.

    During a laboratory activity, appropriate safety equipment was used and safety procedures were followed, as two students worked with hydrated $CuSO_4$. A hydrate is a compound that has water within its crystal structure.

    Student 1 and student 2 each heated their own 3.00-gram sample of hydrated $CuSO_4$. Student 2 determined the percent composition by mass of water in the hydrated $CuSO_4$ to be 37.0%. The accepted value for the percent of water in the hydrated $CuSO_4$ is 36.1%. The final mass values for each student sample are shown in the table below.

Mass Values for Lab Activity

Student	Mass of Hydrated $CuSO_4$ (g)	Mass of $CuSO_4$ After Final Heating (g)	Mass of H_2O in Hydrated $CuSO_4$ (g)
1	3.00	1.98	1.02
2	3.00	1.89	1.11

66 State the number of significant figures in the mass of the hydrated $CuSO_4$ sample used by student 1. [1]

67 Determine the percent composition by mass of water in the hydrated $CuSO_4$ sample, based on the data for student 1. [1]

68 Show a numerical setup for calculating the percent error for the percent composition by mass of water in the hydrated $CuSO_4$ sample as determined by student 2. [1]

Base your answers to questions 69 through 71 on the information below and on your knowledge of chemistry.

Ammonia, $NH_3(g)$, is a compound that is used to manufacture fertilizer for agriculture. This gas is produced by a reaction between nitrogen gas, $N_2(g)$, and hydrogen gas, $H_2(g)$. During this reaction, bonds are both broken and formed. Bond energy is the amount of energy required to break one mole of bonds between atoms in the gas phase. The bond energy of an H–H bond is 436 kilojoules per mole.

69 State the number of electrons shared between the nitrogen atom and one of the hydrogen atoms in an ammonia molecule. [1]

70 Identify the noble gas that has atoms in the ground state with the same electron configuration as the nitrogen atom in a molecule of ammonia. [1]

71 Determine the energy required to break all of the bonds in 0.250 mol of H–H bonds in the $H_2(g)$. [1]

Base your answers to questions 72 and 73 on the information below and on your knowledge of chemistry.

The diagram below represents a sealed, rigid cylinder with a movable piston containing helium gas at 296 K and 1.3 atm.

He(g)
P = 1.3 atm
V = 50.0 mL
T = 296 K
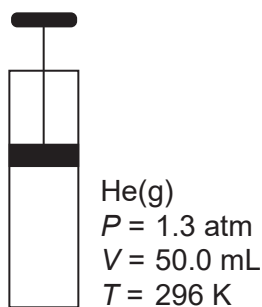
72 Compare the density of the helium in the cylinder when the volume is 50.0 mL to the density of the helium in the cylinder when the volume is decreased to 25.0 mL. [1]

73 State *one* change in temperature and *one* change in pressure that will cause the gas in the cylinder to behave more like an ideal gas. [1]

Base your answers to questions 74 through 76 on the information below and on your knowledge of chemistry.

Four different samples of $NaNO_3(aq)$ are each evaporated to dryness. The solution volume and mass of the dry $NaNO_3(s)$ of each sample are recorded in the table below.

Sample	Volume of NaNO₃(aq) (L)	Mass of dry NaNO₃(s) (g)
1	0.0524	3.56
2	0.0988	6.72
3	0.2017	13.71
4	0.2431	16.53

The number of moles of $NaNO_3(s)$ of each sample was then calculated and used to produce the graph below.

**Moles of NaNO₃ Versus Volume of Solution Sample**
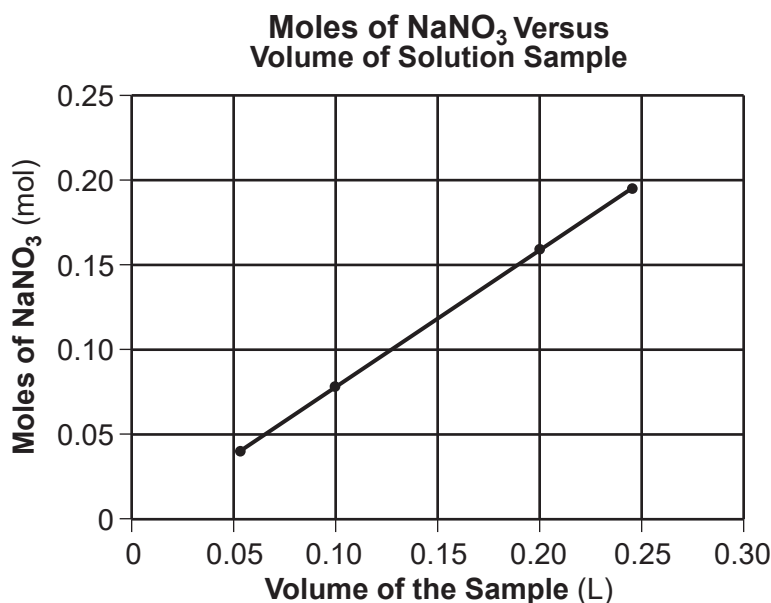
74 Determine the number of moles of $NaNO_3$ in 0.15 L of the solution.   [1]

75 Write a chemical name for $NaNO_3$.   [1]

76 Compare the boiling point of the solution in sample 1 at standard pressure to the boiling point of water at standard pressure.   [1]

Base your answers to questions 77 through 79 on the information below and on your knowledge of chemistry.

Electroplating is an electrolytic process that can be used to coat metal objects with a less reactive metal. The diagram below shows an electroplating cell that includes a power source connected to a copper rod and a bracelet made from a different metal. The rod and bracelet are in an aqueous copper(II) sulfate solution.
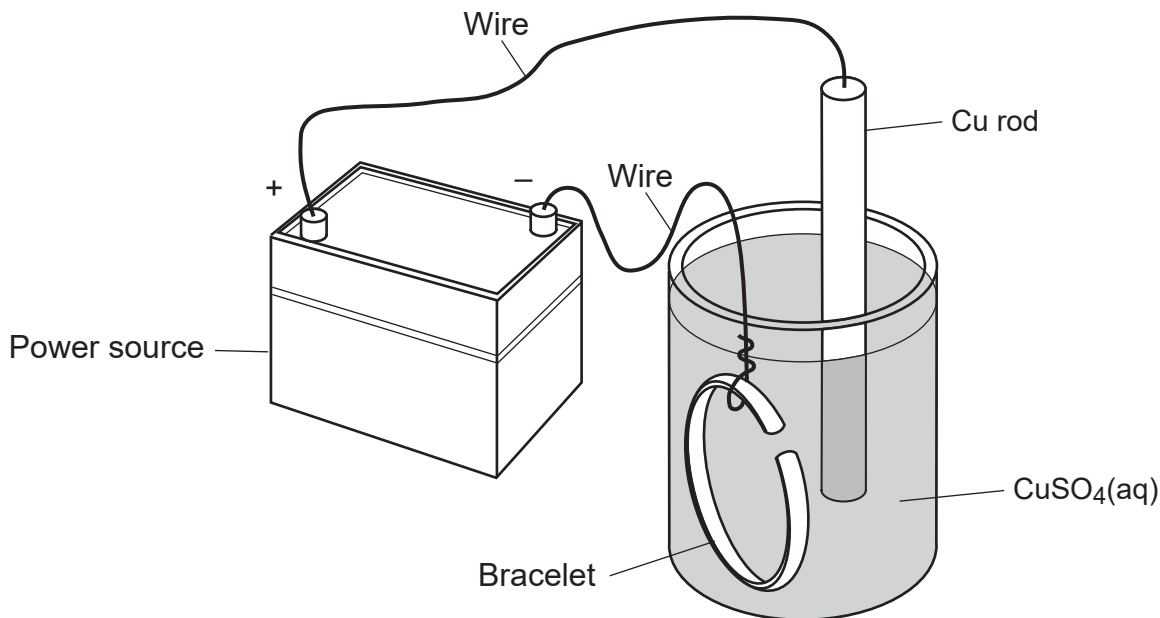
77 Identify the electrode that attracts the Cu^{2+} ions as the cell operates. [1]

78 Determine the oxidation state of sulfur in $CuSO_4$. [1]

79 Write a balanced half-reaction equation for the reduction of Cu^{2+} ions that occurs in this cell. [1]

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

In a titration, 15.0 mL of hydrochloric acid, HCl(aq), of unknown concentration is exactly neutralized by the addition of 8.0 mL of 0.15 M KOH(aq). The pH value of the HCl(aq) solution is 1.1 before the titration begins.
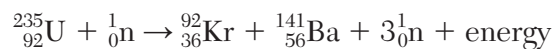
80 Complete the equation *in your answer booklet* for the reaction that occurs in this titration by writing the formula for *each* product. [1]

81 State the pH value of the solution when the H^+(aq) ion concentration in the acid has *decreased* by a factor of 10 compared to its original value. [1]

82 Determine the molarity of the HCl(aq), by using the titration data. [1]

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

Nuclear fission is currently used to produce electricity in a nuclear power plant. One possible fission reaction is represented by the equation below.

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + 3^{1}_{0}\text{n} + \text{energy}$$

The barium-141 decays by beta emission and has a half-life of 18.3 minutes.

83 Based on Table *N*, state the decay mode for U-235. [1]

84 Complete the nuclear equation *in your answer booklet* for the decay of Ba-141, by writing a notation for the missing product. [1]

85 Compare the amount of energy released by the fission of one mole of uranium-235 to the amount of energy released by the combustion of one mole of octane fuel, C_8H_{18}. [1]