The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Wednesday, January 25, 2017 — 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 Which statement describes the location of two types of subatomic particles in a helium atom?

 (1) Protons and neutrons are located in the nucleus.
 (2) Protons and neutrons are located outside the nucleus.
 (3) Protons and electrons are located in the nucleus.
 (4) Protons and electrons are located outside the nucleus.

2 An atom that contains six protons, six neutrons, and six electrons has a mass of approximately

 (1) 12 u   (3) 18 u
 (2) 12 g   (4) 18 g

3 Which term identifies the most probable location of an electron in the wave-mechanical model of the atom?

 (1) anode   (3) nucleus
 (2) orbital   (4) cathode

4 Which element has atoms in the ground state with the greatest number of valence electrons?

 (1) tin   (3) arsenic
 (2) sulfur   (4) fluorine

5 Which group on the Periodic Table has two elements that exist as gases at STP?

 (1) Group 1   (3) Group 16
 (2) Group 2   (4) Group 17

6 Which list of elements contains a metal, a metalloid, and a nonmetal?

 (1) Ag, Si, I_2 (3) K, Cu, Br_2
 (2) Ge, As, Ne   (4) S, Cl_2, Ar

7 What is the charge of the nucleus of a copper atom?

 (1) +1   (3) +29
 (2) +2   (4) +64

8 At STP, $O_2(g)$ and $O_3(g)$ have different properties because $O_3(g)$ has

 (1) more dense nuclei than in $O_2(g)$
 (2) more protons per atom than in $O_2(g)$
 (3) molecules with a different structure than in $O_2(g)$
 (4) molecules with fewer covalent bonds than in $O_2(g)$

9 A compound is a substance composed of two or more elements that are

 (1) physically mixed in a fixed proportion
 (2) physically mixed in a variable proportion
 (3) chemically combined in a fixed proportion
 (4) chemically combined in a variable proportion

10 Which element has the highest boiling point at standard pressure?

 (1) Mg   (3) Rb
 (2) Na   (4) Sr

11 How many pairs of electrons are shared between the nitrogen atoms in a molecule of N_2?

 (1) 5   (3) 3
 (2) 2   (4) 6

12 A molecule must be nonpolar if the molecule

 (1) is linear
 (2) is neutral
 (3) has ionic and covalent bonding
 (4) has a symmetrical charge distribution

13 Which property is used to determine the degree of polarity between two bonded atoms?

(1) density
(2) electronegativity
(3) pressure
(4) temperature

14 In a chemical reaction, a catalyst provides an alternate reaction pathway that

(1) decreases the concentration of the products
(2) increases the concentration of the reactants
(3) has a lower activation energy
(4) has a higher activation energy

15 Which substance can be decomposed by chemical means?

(1) cobalt
(2) krypton
(3) methane
(4) zirconium

16 Which sample of matter represents a mixture?

(1) aqueous ammonia
(2) gaseous ethane
(3) liquid mercury
(4) solid iodine

17 Differences in which property allow the separation of a sample of sand and seawater by filtration?

(1) concentration of ions
(2) volume of sample
(3) mass of sample
(4) particle size

18 Which process is a chemical change?

(1) evaporating an alcohol
(2) subliming of iodine
(3) melting an ice cube
(4) rusting of iron

19 Which term represents an intermolecular force in a sample of water?

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

20 Which sample of matter has particles arranged in a crystalline structure?

(1) $Ne(g)$
(2) $Br_2(\ell)$
(3) $NaCl(aq)$
(4) $CuSO_4(s)$

21 Which term is defined as a measure of the randomness of a system?

(1) heat
(2) entropy
(3) pressure
(4) temperature

22 Which formula represents an alkane?

(1) C_2H_2
(2) C_2H_4
(3) C_3H_4
(4) C_3H_8

23 Which term represents a chemical reaction?

(1) deposition
(2) combustion
(3) sublimation
(4) vaporization

24 Which type of reaction includes esterification and polymerization?

(1) decomposition
(2) neutralization
(3) organic
(4) nuclear

25 In a redox reaction, the total number of electrons lost is

(1) less than the total number of electrons gained
(2) greater than the total number of electrons gained
(3) equal to the total number of electrons gained
(4) unrelated to the total number of electrons gained

26 Which type of equation can represent the oxidation occurring in a reaction?

(1) a double-replacement reaction equation
(2) a half-reaction equation
(3) a neutralization reaction equation
(4) a transmutation reaction equation

27 The electrical conductivity of an aqueous solution depends on the concentration of which particles in the solution?

(1) molecules
(2) electrons
(3) atoms
(4) ions

28 An electrolytic cell differs from a voltaic cell because an electrolytic cell

(1) generates its own energy from a spontaneous physical reaction
(2) generates its own energy from a nonspontaneous physical reaction
(3) requires an outside energy source for a spontaneous chemical reaction to occur
(4) requires an outside energy source for a nonspontaneous chemical reaction to occur

29 A sample of which radioisotope emits particles having the greatest mass?

(1) ^{137}Cs
(2) ^{53}Fe
(3) ^{220}Fr
(4) ^{3}H

30 Which term represents a nuclear reaction?

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

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 configuration represents the distribution of electrons in a potassium atom in the ground state?

(1) 2-8-8-1   (3) 2-8-5
(2) 2-8-7-2   (4) 2-7-6

32 At STP, which element is malleable and a good conductor of electricity?

(1) xenon   (3) platinum
(2) silicon   (4) hydrogen

33 Which general trends in atomic radius and electronegativity are observed as the elements in Period 3 are considered in order of increasing atomic number?

(1) Atomic radius decreases and electronegativity increases.
(2) Atomic radius increases and electronegativity decreases.
(3) Both atomic radius and electronegativity increase.
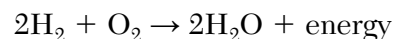(4) Both atomic radius and electronegativity decrease.

34 What is the chemical name for Na_2SO_3?

(1) sodium sulfite   (3) sodium sulfide
(2) sodium sulfate   (4) sodium thiosulfate

35 Which molecular formula is also an empirical formula?

(1) C_6H_6 (3) N_2H_4
(2) H_2O_2 (4) N_2O_5

36 Given the balanced equation representing a reaction:

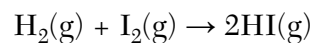$$2H_2 + O_2 \rightarrow 2H_2O + \text{energy}$$

Which mass of oxygen completely reacts with 4.0 grams of hydrogen to produce 36.0 grams of water?

(1) 8.0 g   (3) 32.0 g
(2) 16.0 g   (4) 40.0 g

37 What is the gram-formula mass of $Ca(OH)_2$?

(1) 29 g/mol   (3) 57 g/mol
(2) 54 g/mol   (4) 74 g/mol

38 Given the equation representing a reaction:

$$H_2(g) + I_2(g) \rightarrow 2HI(g)$$

Which statement describes the energy changes that occur in this reaction?

(1) Energy is absorbed as bonds are formed, only.
(2) Energy is released as bonds are broken, only.
(3) Energy is absorbed as bonds are formed, and energy is released as bonds are broken.
(4) Energy is absorbed as bonds are broken, and energy is released as bonds are formed.

39 Based on Table *F*, which compound is *least* soluble in water?

(1) $AlPO_4$ (3) $Ca(OH)_2$
(2) Li_2SO_4 (4) $AgC_2H_3O_2$

40 How many joules of heat are absorbed to raise the temperature of 435 grams of water at 1 atm from 25°C to its boiling point, 100.°C?

(1) 4.5×10^4 J   (3) 2.5×10^7 J
(2) 1.4×10^5 J   (4) 7.4×10^7 J

41 Which temperature represents the highest average kinetic energy of the particles in a sample of matter?

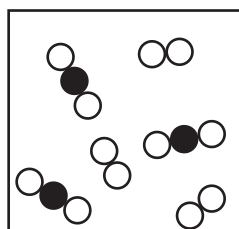(1) 298 K   (3) 27°C
(2) 267 K   (4) 12°C

42 Which change in the H^+ ion concentration of an aqueous solution represents a *decrease* of one unit on the pH scale?

(1) a tenfold increase
(2) a tenfold decrease
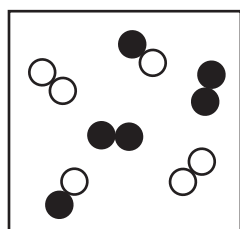(3) a hundredfold increase
(4) a hundredfold decrease

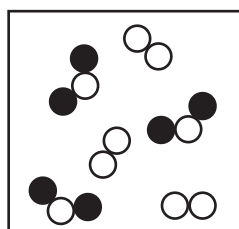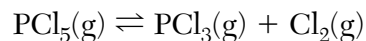43 Which particle diagram represents a mixture of three substances?

| Key |
| --- |
| ◯ = an atom of one element |
| ● = an atom of a different element |

(1)

(2)

(3)
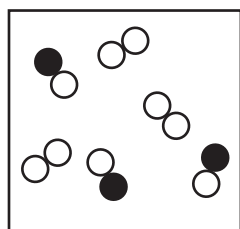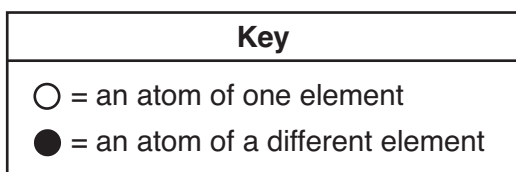
(4)

44 Given the equation representing a system at equilibrium:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Which statement describes this system?

(1) The concentration of $PCl_5(g)$ is increasing.
(2) The concentration of $PCl_5(g)$ is decreasing.
(3) The concentrations of $PCl_5(g)$ and $PCl_3(g)$ are equal.
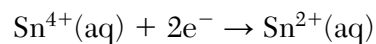(4) The concentrations of $PCl_5(g)$ and $PCl_3(g)$ are constant.

45 Given the formula representing a compound:
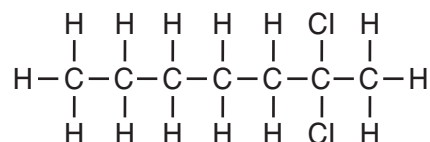
What is the IUPAC name of this compound?

(1) 2-chloroheptane
(2) 6-chloroheptane
(3) 2,2-dichloroheptane
(4) 6,6-dichloroheptane

46 Given the equation representing a reaction:

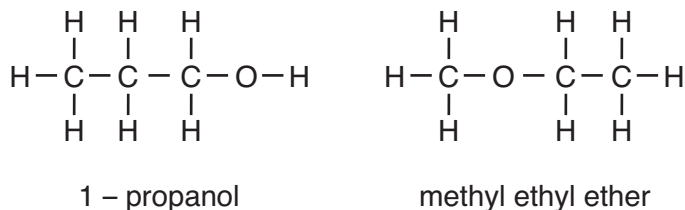$$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$$

Which term best describes this reaction?

(1) ionization   (3) oxidation
(2) neutralization   (4) reduction

47 Which ionic equation represents a spontaneous reaction that can occur in a voltaic cell?

(1) $Cu(s) + Zn(s) \rightarrow Cu^{2+}(aq) + Zn^{2+}(aq)$
(2) $Cu(s) + Zn^{2+}(aq) \rightarrow Cu^{2+}(aq) + Zn(s)$
(3) $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$
(4) $Cu^{2+}(aq) + Zn^{2+}(aq) \rightarrow Cu(s) + Zn(s)$

48 Given the formulas representing two compounds at standard pressure:

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

1 – propanol   methyl ethyl ether

The compounds can be differentiated by their

(1) boiling points
(2) gram-formula masses
(3) numbers of hydrogen atoms
(4) percent compositions by mass of carbon

49 The table below shows the atomic mass and natural abundance of the two naturally occurring isotopes of lithium.

Naturally Occurring Isotopes of Lithium

Isotope	Atomic Mass (u)	Natural Abundance (%)
Li-6	6.015	7.6
Li-7	7.016	92.4

Which numerical setup can be used to determine the atomic mass of naturally occurring lithium?

(1) $(7.6)(6.015 \text{ u}) + (92.4)(7.016 \text{ u})$

(2) $(0.076)(6.015 \text{ u}) + (0.924)(7.016 \text{ u})$

(3) $\dfrac{(7.6)(6.015 \text{ u}) + (92.4)(7.016 \text{ u})}{2}$

(4) $\dfrac{(0.076)(6.015 \text{ u}) + (0.924)(7.016 \text{ u})}{2}$

50 Given the equation representing a reaction at equilibrium:

$$H_2S(aq) + CH_3NH_2(aq) \rightleftharpoons HS^-(aq) + CH_3NH_3^+(aq)$$
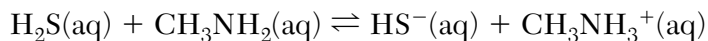
According to one acid-base theory, the forward reaction is classified as an acid-base reaction because

(1) H_2S is a H^+ donor and CH_3NH_2 is a H^+ acceptor
(2) CH_3NH_2 is a H^+ donor and H_2S is a H^+ acceptor
(3) HS^- and $CH_3NH_3^+$ are both H^+ donors
(4) $CH_3NH_3^+$ and HS^- are both H^+ acceptors

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 Explain, in terms of electron configuration, why arsenic and antimony are chemically similar. [1]

52 Identify the element in Period 3 that is an unreactive gas at STP. [1]

53 Compare the energy of an electron in the first shell of a cadmium atom to the energy of an electron in the third shell of the same atom. [1]

Base your answers to questions 54 and 55 on the information below and on your knowledge of chemistry.

The densities for two forms of carbon at room temperature are listed in the table below.

Densities of Two Forms of Carbon

Element Form	Density (g/cm^3)
carbon (graphite)	2.2
carbon (diamond)	3.513

54 Compare the number of carbon atoms in a 0.30-cm^3 sample of graphite and a 0.30-cm^3 sample of diamond. [1]

55 A student calculated the density of a sample of graphite to be 2.3 g/cm^3. Show a numerical setup for calculating the student's percent error for the density of graphite. [1]

Base your answers to questions 56 and 57 on the information below and on your knowledge of chemistry.

A sample of calcium carbonate, $CaCO_3$, has a mass of 42.2 grams. Calcium carbonate has a gram-formula mass of 100. g/mol.

56 Show a numerical setup for calculating the number of moles in the sample of $CaCO_3$. [1]

57 Determine the percent composition by mass of oxygen in the $CaCO_3$. [1]

Base your answers to questions 58 and 59 on the information below and on your knowledge of chemistry.

Carbon monoxide, $CO(g)$, is a toxic gas found in automobile exhaust. The concentration of $CO(g)$ can be decreased by using a catalyst in the reaction between $CO(g)$ and $O_2(g)$. This reaction is represented by the balanced equation below.

$$2CO(g) + O_2(g) \xrightarrow{\text{catalyst}} 2CO_2(g) + \text{energy}$$

58 Explain, in terms of collision theory, why an increase in temperature increases the rate of the reaction.   [1]

59 On the labeled axes *in your answer booklet*, draw the potential energy curve for the reaction represented by this equation.   [1]

_____

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

The diagram and data below represent a gas and the conditions of pressure, volume, and temperature of the gas in a rigid cylinder with a moveable piston.

$N_2(g)$
$P = 1.0$ atm
$V = 2.5$ L
$T = 298$ K
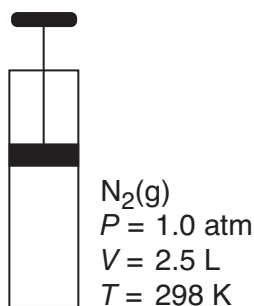
60 Determine the volume of the gas in the cylinder at STP.   [1]

61 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 62 through 65 on the information below and on your knowledge of chemistry.

During a titration, 10.00 mL of acetic acid, $HC_2H_3O_2$(aq), is completely neutralized by adding 12.50 mL of 0.64 M sodium hydroxide, NaOH(aq).

62 Identify the only positive ion in the $HC_2H_3O_2$(aq). [1]

63 State the number of significant figures used to express the volume of the acetic acid. [1]

64 Determine the molarity of the acetic acid. [1]

65 Explain why it is better to use data from multiple trials to determine the molarity of acetic acid, rather than data from a single trial. [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.

Carbon dioxide, CO_2, changes from the solid phase to the gas phase at 1 atm and 194.5 K. In the solid phase, CO_2 is often called dry ice. When dry ice sublimes in air at 298 K, the water vapor in the air can condense, forming a fog of small water droplets. This fog is often used for special effects at concerts and in movie-making.

66 State the direction of heat flow between the dry ice and the water vapor in the air.   [1]

67 At 1 atm and 298 K, compare the potential energies of the water molecules before and after the water vapor condenses.   [1]

68 At 1 atm and 190. K, compare the amount of thermal energy in a 1.0-kilogram block of dry ice to the amount of thermal energy in a 2.0-kilogram block of dry ice.   [1]

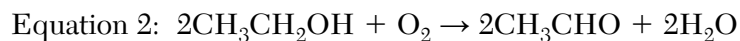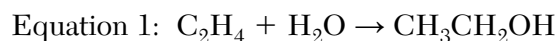Base your answers to questions 69 through 72 on the information below and on your knowledge of chemistry.

A solution of ethylene glycol and water can be used as the coolant in an engine-cooling system. The ethylene glycol concentration in a coolant solution is often given as percent by volume. For example, 100. mL of a coolant solution that is 40.% ethylene glycol by volume contains 40. mL of ethylene glycol diluted with enough water to produce a total volume of 100. mL. The graph below shows the freezing point of coolants that have different ethylene glycol concentrations.

Freezing Points of Coolants

Percent by Volume of Ethylene Glycol (%)
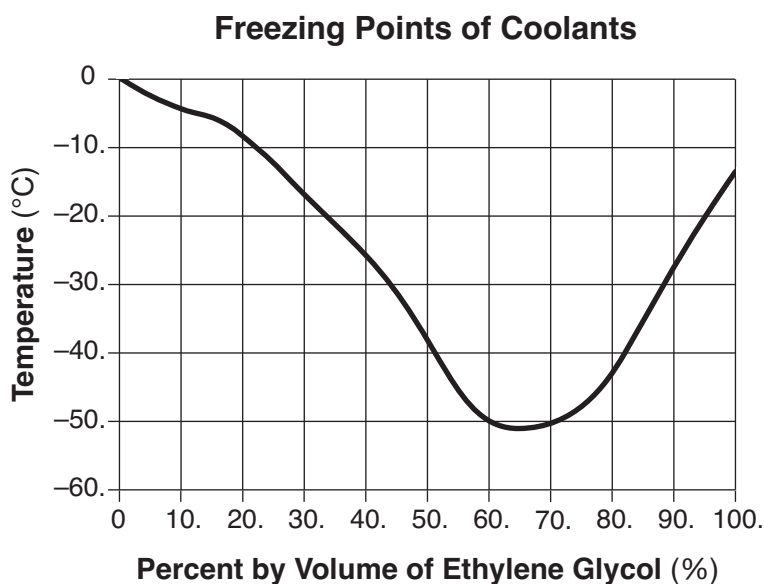
69 Explain, in terms of particle distribution, why a coolant solution is a homogeneous mixture. [1]

70 Explain, in terms of the molecular polarity, why ethylene glycol dissolves in water to form a solution. [1]

71 Identify the percent by volume of ethylene glycol in a solution that freezes at −10.°C. [1]

72 One engine-cooling system has a volume of 6400 mL. Determine the volume of ethylene glycol in the completely filled engine-cooling system when the concentration of ethylene glycol is 50.% by volume. [1]

Base your answers to questions 73 through 77 on the information below and on your knowledge of chemistry.

Molecules containing two carbon atoms and a functional group have many home and industrial uses. These compounds can be produced by a variety of reactions, as shown by the equations below.

Equation 1: $C_2H_4 + H_2O \rightarrow CH_3CH_2OH$

Equation 2: $2CH_3CH_2OH + O_2 \rightarrow 2CH_3CHO + 2H_2O$

Equation 3: $2CH_3CHO + O_2 \rightarrow 2CH_3COOH$

73 Explain, in terms of bonding, why the hydrocarbon reactant in equation 1 is unsaturated. [1]

74 Draw a structural formula of the ethanal molecule in equation 2. [1]

75 Explain, in terms of atoms, why CH_3CH_2OH and CH_3CHO are *not* isomers of each other. [1]

76 Identify the class of organic compounds to which the product in equation 3 belongs. [1]

77 Determine the number of moles of oxygen required to completely react with six moles of CH_3CHO in equation 3. [1]

Base your answers to questions 78 and 79 on the information below and on your knowledge of chemistry.

The hydrangea is a flowering plant. The color of the flowers it produces can change depending on the pH value of the soil in which the plant grows. Adding aluminum sulfate makes the soil more acidic and adding calcium hydroxide makes the soil more basic.

A student performed an experiment by varying soil pH and recording the color of the flowers. The following table summarizes the results of the experiment.

Hydrangea Soil pH and Flower Color

Soil pH	Flower Color
5.5 and below	blue
between 5.5 and 6.5	purple
6.5 and above	pink

78 Identify the independent variable in this experiment. [1]

79 Hydrangea plants can be grown in soil that turns litmus red. What color are the flowers of the plants grown in this soil? [1]

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

The diagram and balanced ionic equation below represent two half-cells connected to produce an operating voltaic cell in a laboratory investigation. The half-cells are connected by a salt bridge.

Voltaic Cell

$$Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$$
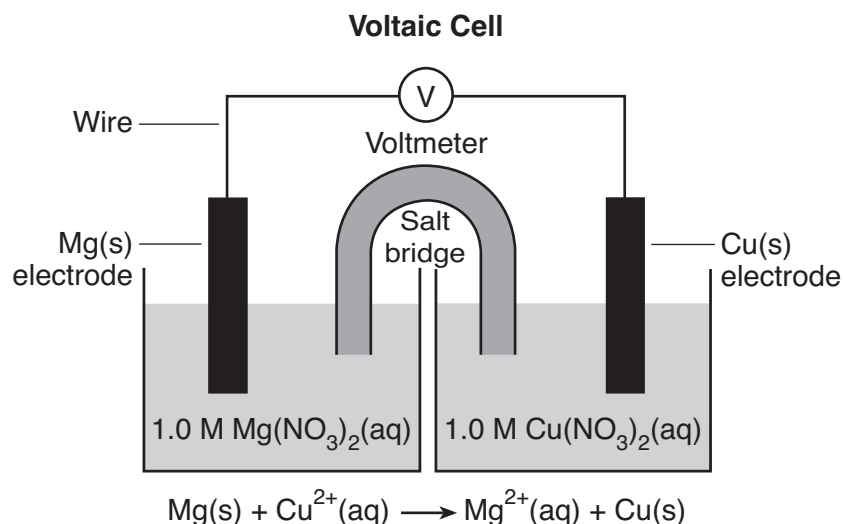
80 Determine the oxidation number of nitrogen in the negative ion in the aqueous solutions. [1]

81 State the purpose of the salt bridge in this voltaic cell. [1]

82 Explain, in terms of atoms and ions, why the mass of the Mg(s) electrode decreases as the cell operates. [1]

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

The radioisotope Mo-99 naturally decays to produce the metastable isotope Tc-99m, which is used in medical diagnosis. A doctor can obtain images of organs and bones by injecting a patient with a solution of Tc-99m. The half-life of the metastable Tc-99m is six hours.

83 Complete the nuclear equation *in your answer booklet* for the nuclear decay of Mo-99. [1]

84 State *both* the number of protons and the number of neutrons in a Tc-99 nuclide. [1]

85 Determine the fraction of an original sample of metastable Tc-99m that remains unchanged after 24 hours. [1]