

# Large-Type Edition

The University of the State of New York  
REGENTS HIGH SCHOOL EXAMINATION

## PHYSICAL SETTING CHEMISTRY

Thursday, June 20, 2024 — 1:15 to 4:15 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 START THIS EXAMINATION 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 description of the atom is based on the results of the gold foil experiment in the early 1900s?

- (1) Atoms are small, dense, indivisible spheres.
- (2) Atoms are composed of protons, electrons, and neutrons.
- (3) Atoms have small, dense, positively charged nuclei.
- (4) Atoms have electrons with wavelike properties.

2 According to the electron cloud model, which term is defined as the most probable location of an electron in an atom?

- (1) configuration
- (2) nucleus
- (3) orbital
- (4) spectrum

3 Which change occurs when an electron returns from a higher energy state to a lower energy state?

- (1) An ionic compound is formed, and energy is emitted.
- (2) An ionic compound is formed, and energy is absorbed.
- (3) A specific amount of energy is absorbed.
- (4) A specific amount of energy is emitted.

4 Which phrase describes the different isotopes of an element?

- (1) same number of electrons and a different number of protons
- (2) same number of protons and a different number of electrons
- (3) same number of protons and a different number of neutrons
- (4) same number of neutrons and a different number of protons

5 Which statement describes a chemical property of sodium?

- (1) It is silver in color.
- (2) It has a density of  $0.97 \text{ g/cm}^3$  at room temperature.
- (3) It has atoms with an atomic radius of 160 pm.
- (4) It is highly reactive with water.

6 Oxygen can exist as diatomic oxygen gas,  $\text{O}_2(\text{g})$ , or ozone,  $\text{O}_3(\text{g})$ . These two forms of oxygen have

- (1) the same molecular structure and the same properties
- (2) different molecular structures and different properties
- (3) the same molecular structure and different properties
- (4) different molecular structures and the same properties

7 Which formula contains a polyatomic ion?

- (1) KCN
- (2)  $\text{K}_2\text{S}$
- (3)  $\text{AlBr}_3$
- (4)  $\text{Al}_2\text{O}_3$

8 What information about  $\text{C}_4\text{H}_{10}$  can be determined from its structural formula, but *not* determined from its molecular formula?

- (1) physical state
- (2) molar mass
- (3) ratio of different atoms
- (4) arrangement of the atoms

9 Which quantity is conserved in all chemical reactions?

- (1) charge
- (2) density
- (3) moles
- (4) volume

10 What do the coefficients in a balanced chemical equation indicate about the substances in the equation?

- (1) mass ratios
- (2) mole ratios
- (3) empirical formulas
- (4) molecular formulas

11 At STP, which substance has metallic bonding?

- (1) argon
- (2) barium chloride
- (3) sulfur dioxide
- (4) titanium

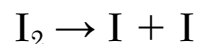
12 How many pairs of electrons are shared between the nitrogen atoms in a molecule of  $\text{N}_2$ ?

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

13 Which formula represents a molecule with an asymmetrical distribution of charge?

- (1)  $\text{Cl}_2$
- (2)  $\text{CO}_2$
- (3)  $\text{CH}_4$
- (4)  $\text{H}_2\text{O}$

14 Given the equation representing a reaction:



What occurs during this reaction?

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

15 The electronegativity difference between the atoms in a molecule of  $\text{HF}$  can be used to determine the

- (1) energy of the molecule
- (2) functional group of molecule
- (3) polarity of the bond in the molecule
- (4) volume of the atoms in the molecule

16 Which sample of matter is classified as a mixture?

- (1)  $\text{NaCl}(\text{s})$
- (2)  $\text{CH}_3\text{OH}(\ell)$
- (3)  $\text{SO}_2(\text{g})$
- (4)  $\text{KNO}_3(\text{aq})$

17 At STP, which property of tungsten remains the same for all samples of tungsten?

- (1) density
- (2) mass
- (3) surface area
- (4) thermal energy

18 An element is composed of atoms that must have

- (1) the same atomic mass
- (2) the same atomic number
- (3) a different number of protons
- (4) a different number of electrons

19 Compared to a 2.0 M aqueous solution of  $\text{KI}$  at 1.0 atm, water at 1.0 atm 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 a higher freezing point

20 Which statement describes the particles of an ideal gas, based on the kinetic molecular theory?

- (1) The particles have attractive forces between them.
- (2) The particles move in random, constant, straight-line motion.
- (3) The particles collide, increasing the total energy of the system.
- (4) The particles are separated by distances that are small compared to their size.

21 Chemical reactions are most likely to occur when reacting particles collide with the

- (1) proper energy and proper orientation
- (2) proper first ionization energy and proper molecular symmetry
- (3) same mass and the same number of electrons
- (4) same number of valence electrons and the same number of electron shells

22 At STP, a 2.0-liter sample of nitrogen gas and a 2.0-liter sample of oxygen gas have equal

- (1) atomic masses
- (2) numbers of molecules
- (3) densities
- (4) boiling points

23 Based on Table *H*, which compound has the *weakest* intermolecular forces at 75°C?

- (1) ethanoic acid
- (2) ethanol
- (3) propanone
- (4) water

24 Which term identifies a force of attraction that exists between molecules of water?

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

25 Which process results in an increase in disorder?

- (1) the condensation of water vapor
- (2) the freezing of liquid ethanol
- (3) the sublimation of solid iodine
- (4) the solidification of melted sodium chloride

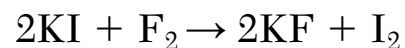
26 Systems in nature tend to undergo changes that result in

- (1) an increase in both energy and entropy
- (2) a decrease in both energy and entropy
- (3) an increase in energy and a decrease in entropy
- (4) a decrease in energy and an increase in entropy

27 What is the general formula for the homologous series that includes ethyne?

- (1)  $C_nH_n$                       (3)  $C_nH_{2n+2}$   
(2)  $C_nH_{2n}$                     (4)  $C_nH_{2n-2}$

28 Given the equation representing a reaction:



When 2.0 moles of electrons are gained by fluorine, how many moles of electrons are lost by iodine?

- (1) 1.0 mol                      (3) 3.0 mol  
(2) 2.0 mol                      (4) 4.0 mol

29 Which compound is an Arrhenius base?

- (1)  $H_2SO_4$                       (3)  $Ca(OH)_2$   
(2)  $NaCl$                         (4)  $KNO_3$

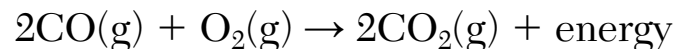
30 Which statement describes a benefit of fission?

- (1) Fission produces nuclear power.  
(2) Fission increases the possibility of nuclear accidents.  
(3) Fission increases the possibility of biological exposure.  
(4) Fission produces waste products that need long-term storage.





35 Given a balanced equation representing a reaction:



Which mass of  $\text{O}_2(\text{g})$  reacts completely with 5.6 grams of  $\text{CO}(\text{g})$  to produce 8.8 grams of  $\text{CO}_2(\text{g})$ ?

- (1) 1.6 g                      (3) 3.2 g  
(2) 2.8 g                      (4) 14.4 g

36 Which numerical setup can be used to calculate the formula mass of  $\text{C}_9\text{H}_{11}\text{NO}_2$ ?

- (1)  $9 \text{ u} + 11 \text{ u} + 1 \text{ u} + 2 \text{ u}$   
(2)  $12 \text{ u} + 1 \text{ u} + 14 \text{ u} + 16 \text{ u}$   
(3)  $9(6 \text{ u}) + 11(1 \text{ u}) + 1(7 \text{ u}) + 2(8 \text{ u})$   
(4)  $9(12 \text{ u}) + 11(1 \text{ u}) + 1(14 \text{ u}) + 2(16 \text{ u})$

37 Based on Table *F*, which compound is most soluble in water?

- (1) calcium bromide              (3) silver carbonate  
(2) lead(II) sulfate                (4) tin(II) hydroxide

38 Based on Table *G*, which combination of solute and solvent will form a saturated solution when thoroughly mixed at  $20.^{\circ}\text{C}$ ?

- (1) 15 grams  $\text{KClO}_3$  in 100. grams  $\text{H}_2\text{O}$   
(2) 20. grams  $\text{KCl}$  in 100. grams  $\text{H}_2\text{O}$   
(3) 30. grams  $\text{NaCl}$  in 100. grams  $\text{H}_2\text{O}$   
(4) 35 grams  $\text{KI}$  in 100. grams  $\text{H}_2\text{O}$

39 A solution has a mass of 2000. grams and contains 0.050 gram of dissolved solute. What is the concentration in parts per million of this solution?

- (1) 5.0 ppm                      (3) 50. ppm  
(2) 25 ppm                      (4) 100. ppm

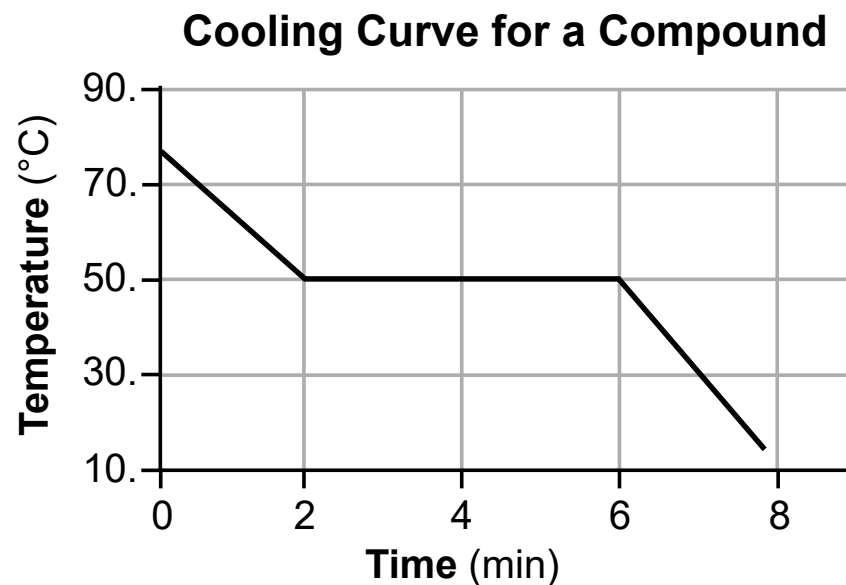
40 A person with a body temperature of  $37^{\circ}\text{C}$  holds a cup of hot water in their hand. The temperature of the cup is  $44^{\circ}\text{C}$ . The air temperature is  $22^{\circ}\text{C}$ . Which phrase describes a heat transfer that occurs in this system?

- (1) from the air to the cup  
(2) from the hand to the cup  
(3) from the air to the hand  
(4) from the cup to the hand

41 What is the amount of heat absorbed to completely melt 26.2 grams of  $\text{H}_2\text{O}(s)$  at  $0^\circ\text{C}$ ?

- (1)  $8.75 \times 10^3 \text{ J}$                       (3)  $5.92 \times 10^4 \text{ J}$   
(2)  $3.66 \times 10^4 \text{ J}$                       (4)  $2.48 \times 10^5 \text{ J}$

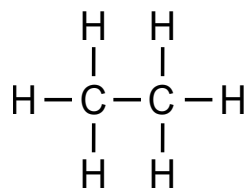
42 The graph below shows a compound being cooled, beginning in the liquid phase.



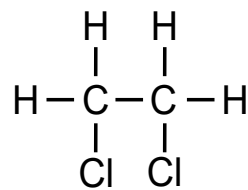
Which statement describes the average kinetic energy and the potential energy between minute 2 and minute 6?

- (1) Average kinetic energy and potential energy both decrease.  
(2) Average kinetic energy and potential energy both remain constant.  
(3) Average kinetic energy remains constant and potential energy increases.  
(4) Average kinetic energy remains constant and potential energy decreases.

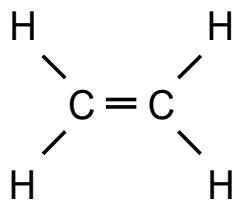
43 Which formula represents a saturated hydrocarbon?



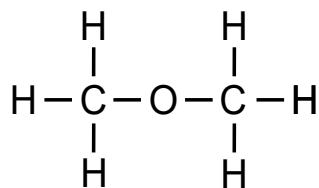
(1)



(3)

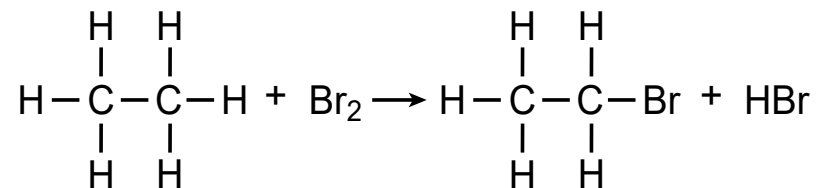


(2)



(4)

44 Given an equation representing a reaction:



Which type of organic reaction is represented by this equation?

- (1) addition                      (3) fermentation  
(2) polymerization              (4) substitution

45 In which compound does sulfur have an oxidation state of +4?

- (1)  $\text{K}_2\text{S}$                               (3)  $\text{SO}_2$   
(2)  $\text{CaS}$                               (4)  $\text{SO}_3$

46 Which solution is the best conductor of electricity?

- (1) 0.0010 M  $\text{CaCl}_2(\text{aq})$   
(2) 0.010 M  $\text{CaCl}_2(\text{aq})$   
(3) 0.10 M  $\text{CaCl}_2(\text{aq})$   
(4) 1.0 M  $\text{CaCl}_2(\text{aq})$



## 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.

Compounds that contain the element boron, such as boric acid and sodium borate, produce a green flame when a sample of one of these compounds is placed in a laboratory burner flame. If this flame is viewed through a spectroscope, a bright-line spectrum is seen.

- 51 State how the bright-line spectra of known elements can be used to identify an unknown element whose bright-line spectrum was viewed through a spectroscope. [1]
- 52 State, in terms of electrons in shells, why the electron configuration 2-2-1 is an excited state electron configuration of a boron atom. [1]
-

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

Silicon is an element in Group 14 on the Periodic Table. The atomic mass and natural abundance for the three naturally occurring isotopes of silicon are shown in the table below.

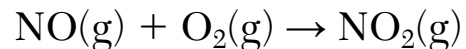
**Naturally Occurring Isotopes of Silicon**

<b>Isotope Notation</b>	<b>Atomic Mass (u)</b>	<b>Natural Abundance (%)</b>
Si-28	27.98	92.22
Si-29	28.98	4.69
Si-30	29.97	3.09

- 53 Draw a Lewis electron-dot diagram for an atom of silicon in the ground state. [1]
- 54 Compare the energy of an electron in the first shell of a silicon atom to the energy of an electron in the third shell of the same atom. [1]
- 55 Show a numerical setup for calculating the atomic mass of the element silicon. [1]
-

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

The unbalanced equation below shows a reaction between nitrogen monoxide gas and oxygen gas to produce nitrogen dioxide gas.



56 State, in terms of reactants and product, why this reaction is a synthesis reaction. [1]

57 Balance the equation *in your answer booklet* for the reaction, using the *smallest* whole-number coefficients. [1]

58 Determine the percent composition by mass of oxygen in the product,  $\text{NO}_2$  (gram-formula mass = 46 g/mol). [1]

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Base your answers to questions 59 and 60 on the information below and on your knowledge of chemistry.

The ionic radii of four Group 17 elements are given in the table below.

**Ionic Radii of Four Group 17 Elements**

<b>Ion</b>	<b>Ionic Radius (pm)</b>
F <sup>-</sup>	133
Cl <sup>-</sup>	181
Br <sup>-</sup>	196
I <sup>-</sup>	220.

- 59 Identify the noble gas that has atoms in the ground state with the same electron configuration as a Br<sup>-</sup> ion in the ground state. [1]
- 60 State, in terms of electrons, why the ionic radius of a Group 17 element is larger than the atomic radius for the same element. [1]
-

Base your answers to questions 61 and 62 on the information below and on your knowledge of chemistry.

The diagram below represents two sealed, rigid containers and the conditions of pressure, volume, and temperature for each container. Container A is filled with  $\text{N}_2(\text{g})$  and container B is filled with  $\text{O}_2(\text{g})$ .

Container A	Container B
$\text{N}_2(\text{g})$	$\text{O}_2(\text{g})$
$P = 101.3 \text{ kPa}$	$P = 101.3 \text{ kPa}$
$V = 750. \text{ mL}$	$V = 750. \text{ mL}$
$T = 298 \text{ K}$	$T = 298 \text{ K}$

- 61 Explain, in terms of the strength of intermolecular forces, why the gas in container B at standard pressure has a higher boiling point than the gas in container A at standard pressure. [1]
- 62 In the space *in your answer booklet*, show a numerical setup for calculating the pressure if the gas in container B is cooled to standard temperature. [1]
-

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Base your answers to questions 63 through 65 on the information below and on your knowledge of chemistry.

The table below shows the formulas of three organic compounds, and a chemical name for two of the compounds.

### Three Organic Compounds

Compound	Name	Formula
1	propyl butanoate	$\begin{array}{ccccccccccc} & \text{H} & \text{H} & \text{H} & \text{O} & & \text{H} & \text{H} & \text{H} & & \\ &   &   &   &    & &   &   &   & & \\ \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{C} & - \text{O} & - \text{C} & - \text{C} & - \text{C} & - \text{H} & \\ &   &   &   & & &   &   &   & & \\ & \text{H} & \text{H} & \text{H} & & & \text{H} & \text{H} & \text{H} & & \end{array}$
2	?	$\begin{array}{ccccccc} & \text{H} & \text{H} & \text{O} & & & \\ &   &   &    & & & \\ \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{OH} & & \\ &   &   & & & & \\ & \text{H} & \text{H} & & & & \end{array}$
3	2-propanol	$\begin{array}{ccccccc} & \text{H} & \text{OH} & \text{H} & & & \\ &   &   &   & & & \\ \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{H} & & \\ &   &   &   & & & \\ & \text{H} & \text{H} & \text{H} & & & \end{array}$

Questions 63-65 are continued on the next page.

## Questions 63–65 continued

- 63 Identify the element in these three compounds that allows them to be classified as organic compounds. [1]
- 64 Identify the class of organic compound to which compound 1 belongs. [1]
- 65 Write a chemical name for compound 2. [1]
- 

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## 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 69 on the information below and on your knowledge of chemistry.

The Periodic Table of the Elements has changed over the past 150 years. During this time, many elements have been added as they were discovered. The elements 113, 115, 117, and 118 in Period 7 were named in 2016. Their official names have been approved by the International Union of Pure and Applied Chemistry (IUPAC). The table below lists the names, symbols, and atomic numbers for these four elements.

**Recently Named Elements in Period 7**

<b>Element Name</b>	<b>Atomic Number</b>	<b>Element Symbol Prior to 2016</b>	<b>Element Symbol as of 2016</b>
nihonium	113	Uut	Nh
moscovium	115	Uup	Mc
tennessine	117	Uus	Ts
oganesson	118	Uuo	Og

**Questions 66-69 are continued on the next page.**

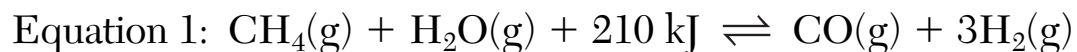
## Questions 66–69 continued

- 66 Identify the element in this table that is located on the Periodic Table of the Elements in the group classified as noble gases. [1]
- 67 Explain, in terms of valence electrons, why the elements nihonium and tennessine would be expected to differ in their chemical properties. [1]
- 68 Describe the general trend in first ionization energy values as the five elements above moscovium in Group 15 on the Periodic Table of the Elements are considered in order of increasing atomic number. [1]
- 69 State, in terms of protons, why tennessine is listed before oganesson in Period 7 on the Periodic Table of the Elements. [1]
- 

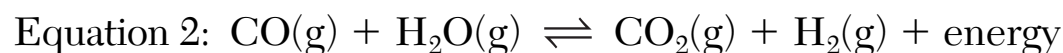
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Base your answers to questions 70 through 73 on the information below and on your knowledge of chemistry.

Hydrogen gas is needed for many industrial chemical reactions. An equilibrium system that includes the use of a catalyst produces hydrogen from methane and steam is shown in equation 1 below.



Another equilibrium system produces hydrogen gas as represented by equation 2 below.



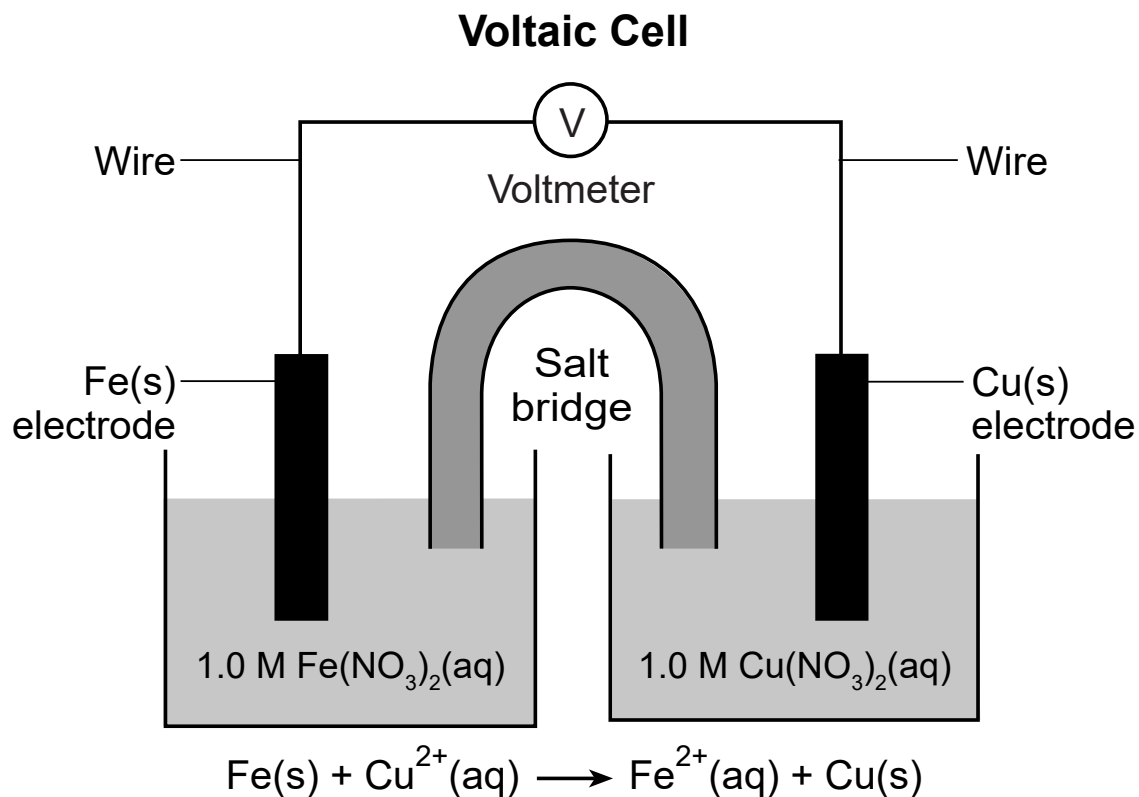
- 70 Compare the rate of the forward reaction to the rate of the reverse reaction for the equilibrium system at equilibrium represented by equation 1. [1]
- 71 State how the equilibrium shifts when the temperature of the equilibrium system at equilibrium represented by equation 1 is increased. [1]
- 72 State, in terms of activation energy, why the catalyst increases the rate of the forward reaction represented in equation 1. [1]
- 73 On the labeled axes *in your answer booklet*, draw a potential energy diagram for the forward reaction represented in equation 2. [1]
-



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Base your answers to questions 74 through 77 on the information below and on your knowledge of chemistry.

The diagram and balanced ionic equation below represent an operating voltaic cell.



Questions 74-77 are continued on the next page.

## Questions 74–77 continued

- 74 State the form of energy that is converted to electrical energy during the operation of this voltaic cell. [1]
- 75 Identify *one* metal from Table *J* that is more easily oxidized than copper and *less* easily oxidized than iron. [1]
- 76 State the purpose of the salt bridge in completing the circuit in this cell. [1]
- 77 Write a balanced equation for the half-reaction that occurs in the copper half-cell. [1]
- 

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Base your answers to questions 78 through 81 on the information below and on your knowledge of chemistry.

In a laboratory investigation, a 0.010 M NaOH(aq) solution with a pH value of 12.00 is used to determine the molarity of a HCl(aq) solution. A 10.0-milliliter sample of the HCl(aq) is exactly neutralized by 20.0 milliliters of the 0.010 M NaOH(aq). During this laboratory activity, appropriate safety equipment is used and safety procedures are followed.

78 State the color of the indicator litmus in a sample of the original NaOH(aq) solution. [1]

79 Determine the pH value of a solution that has a hydronium ion concentration 100 times greater than the original NaOH(aq) solution. [1]

80 Identify the positive ion in the original HCl(aq) solution. [1]

81 Determine the molarity of the HCl(aq) solution using the titration data. [1]

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Base your answers to questions 82 through 85 on the information below and on your knowledge of chemistry.

Spacecraft sometimes use a nuclear power source that produces electricity from the heat released by the decay of radioisotopes. Two radioisotopes that have been used in these nuclear power sources are plutonium-238 and americium-241. Both the Pu-238 and Am-241 emit alpha radiation and gamma radiation. The half-life of Am-241 is 432.7 years. Other sources of electrical energy for some spacecraft have been solar panels and batteries.

- 82 Determine the fraction of Am-241 remaining from an original sample after 865.4 years. [1]
- 83 Compare the penetrating power of the alpha particles to the penetrating power of the gamma radiation. [1]
- 84 Complete the nuclear equation for the alpha decay of Pu-238 by writing a notation for the missing nuclide. [1]
- 85 Compare the energy released by the radioactive decay of 1.0 kilogram of Pu-238 in this nuclear power source to the energy released by 1.0 kilogram of chemical reactants in a battery. [1]
-

