Large-Type Edition

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING

CHEMISTRY

Friday, January 26, 2024 — 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 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 particles surround the nucleus of a neon atom?

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

2 Which conclusion was proposed as a result of an experiment during which some alpha particles were deflected while passing through a thin sheet of gold foil?

(1) Atoms are hard, indivisible spheres.
(2) Atoms have small, dense, positive nuclei.
(3) Atoms contain negatively charged particles.
(4) Atoms have electrons with wavelike properties.

3 The mass of each proton and each neutron is approximately equal to

(1) 1 g
(2) 1 mL
(3) 1 u
(4) 1 mol

4 Which statement describes the relationship between two electrons in an atom of magnesium in the ground state?

(1) An electron in the first shell has the same amount of energy as an electron in the second shell.
(2) An electron in the first shell has a greater amount of energy than an electron in the second shell.
(3) An electron in the second shell has the same amount of energy as an electron in the third shell.
(4) An electron in the third shell has a greater amount of energy than an electron in the second shell.

5 As an atom in the ground state changes to an atom in an excited state, the atom

(1) absorbs energy
(2) releases energy
(3) increases in mass number
(4) decreases in mass number

6 Which statement describes a chemical property of copper?

(1) Copper has a red-orange color.
(2) Copper can be flattened into sheets.
(3) Copper reacts with oxygen.
(4) Copper conducts an electric current.

7 At STP, two forms of solid carbon, diamond and graphite, have different properties because

(1) diamond has a different percent composition than graphite
(2) diamond has more electrons per atom than graphite
(3) diamond has stronger hydrogen bonding than graphite
(4) diamond has a different crystal structure than graphite

8 Which element in Period 2 has the highest first ionization energy?

(1) boron
(2) lithium
(3) neon
(4) nitrogen

9 Which phrase describes a specific compound?

(1) can contain only one element
(2) can be physically separated into elements
(3) is composed of elements chemically combined in a definite ratio
(4) is composed of elements mixed in proportions that can vary

10 Which type of chemical formula shows the arrangement of the atoms in a molecule?

(1) empirical formula
(2) general formula
(3) molecular formula
(4) structural formula

11 A 2.5 L sample of $SO_2(g)$ at STP and a 2.5 L sample of $CO_2(g)$ at STP can be differentiated by comparing their

(1) masses
(2) phases
(3) temperatures
(4) volumes

12 Which terms identify the two different major categories of compounds?

(1) covalent and molecular
(2) covalent and thermal
(3) ionic and molecular
(4) ionic and thermal

13 Which molecule of an element contains a multiple covalent bond?

(1) Br_2
(2) F_2
(3) H_2
(4) O_2

14 Which molecule is symmetrical in *both* shape and distribution of charge?

(1) HCl
(2) H_2O
(3) NH_3
(4) CH_4

15 What occurs when two atoms of bromine react to form a molecule of bromine?

(1) A bond is broken as energy is released.
(2) A bond is broken as energy is absorbed.
(3) A bond is formed as energy is released.
(4) A bond is formed as energy is absorbed.

16 Atoms of which element have the strongest attraction for electrons in a chemical bond?

(1) fluorine
(2) nitrogen
(3) phosphorus
(4) potassium

17 Heat flows from an object at a temperature of 20.°C to an object at a temperature of

(1) 15°C
(2) 25°C
(3) 35°C
(4) 45°C

18 According to the kinetic molecular theory, an ideal gas has particles with

(1) large volume
(2) large atomic radii
(3) no attractive forces
(4) no random motion

19 Which sample at STP contains the same number of atoms as 2.0 liters of He(g) at STP?

(1) 1.0 liter of Ar(g)
(2) 2.0 liters of Ar(g)
(3) 3.0 liters of Ne(g)
(4) 4.0 liters of Ne(g)

20 All chemical systems at equilibrium have equal

(1) masses of reactants and products
(2) concentrations of reactants and products
(3) rates of forward and reverse reactions
(4) activation energies of forward and reverse reactions

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

(1) $(PE_{products}) + (PE_{reactants})$
(2) $(PE_{products}) - (PE_{reactants})$
(3) $(PE_{products}) \div (PE_{reactants})$
(4) $(PE_{products}) \times (PE_{reactants})$

22 Which phase change represents an increase in entropy?

(1) liquid to gas
(2) liquid to solid
(3) gas to solid
(4) gas to liquid

23 Systems in nature tend to change toward

(1) lower energy and less disorder
(2) lower energy and greater disorder
(3) higher energy and less disorder
(4) higher energy and greater disorder

24 Which name represents a hydrocarbon?

(1) 1–hexene
(2) 1–iodohexane
(3) 3–hexanone
(4) 3–hexanol

25 Which process occurs at the anode in an electrolytic cell?

(1) addition
(2) combustion
(3) oxidation
(4) reduction

26 Which formula represents an electrolyte?

(1) H_2O
(2) CCl_4
(3) H_2SO_4
(4) $C_6H_{12}O_6$

27 Which formula represents an Arrhenius acid?

(1) KCl
(2) HCl
(3) NH_3
(4) KOH

28 According to one acid-base theory, an acid is a substance that

(1) donates hydroxide ions
(2) donates hydrogen ions
(3) accepts hydroxide ions
(4) accepts hydrogen ions

29 Which nuclear emission has the greatest mass and ionizing power?

(1) alpha particle
(2) beta particle
(3) gamma radiation
(4) positron

30 Which statement describes a benefit of the nuclear reaction that occurs in a nuclear power plant?

(1) Large amounts of water are needed to cool the nuclear reactor.
(2) The power plant reaction can be used in dating geologic formations.
(3) Radioactive isotopes are stored for a very long time at the power plant site.
(4) A large amount of energy is produced from a small amount of a radioisotope.

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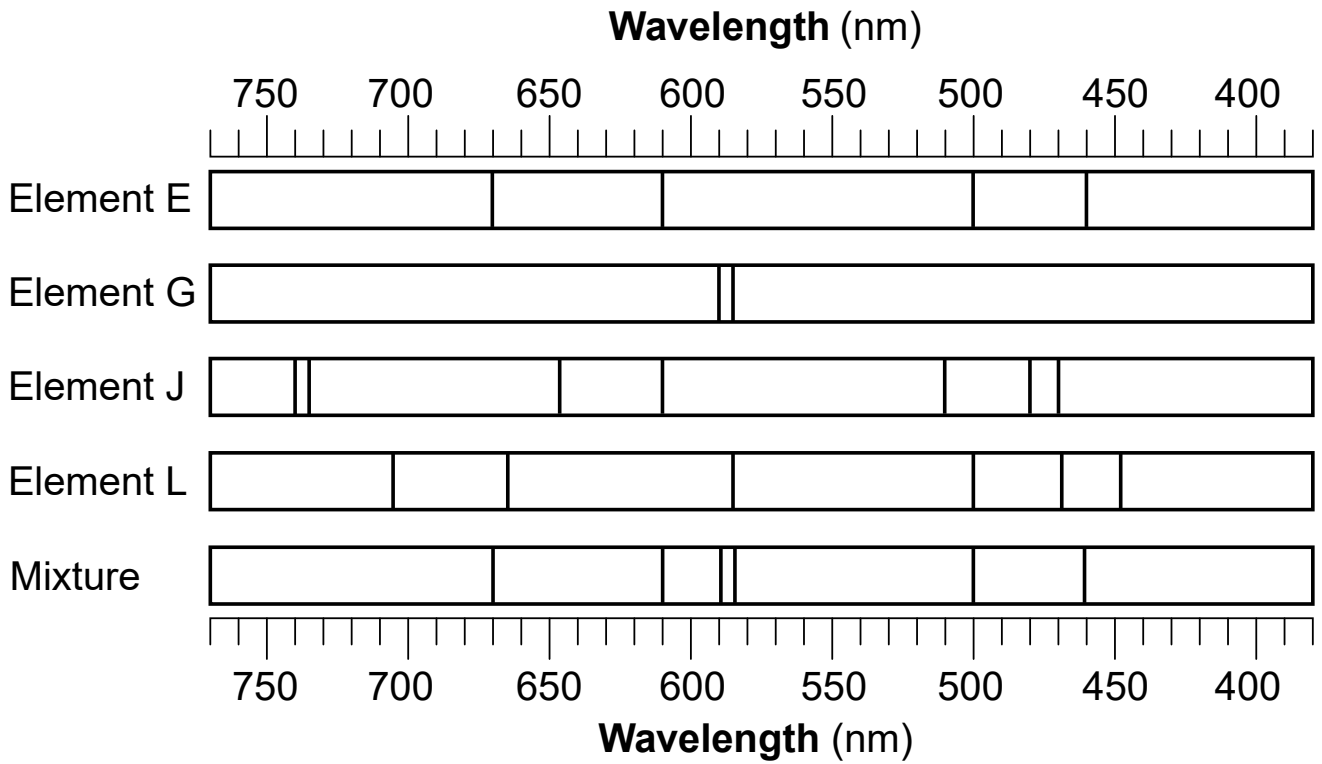
Part B–1
Answer all questions in this part.

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 The bright-line spectra produced by four elements and a mixture of two of these elements are represented in the diagram below.

Bright-Line Spectra of Four Elements and a Mixture

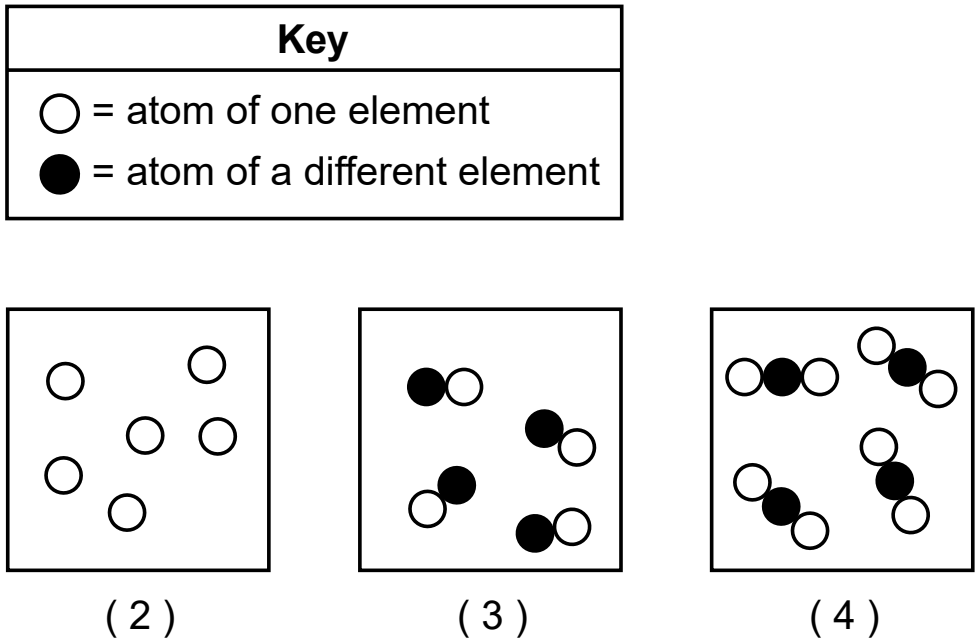


Question 31 is continued on the next page.

Which elements are present in the mixture?

(1) *L* and *G*
(2) *L* and *J*
(3) *E* and *G*
(4) *E* and *J*

32 Which particle model diagram represents a noble gas at STP?



33 A student determines the density of a copper sample at room temperature to be 9.46 g/cm^3. Based on Table *S*, what is the student's percent error in determining the density of copper?

(1) 0.50%
(2) 5.0%
(3) 5.3%
(4) 5.6%

34 What is the gram-formula mass of $Mg(NO_3)_2$?

(1) 86 g/mol
(2) 134 g/mol
(3) 148 g/mol
(4) 172 g/mol

35 Compared to a rubidium atom, a Rb^+ ion has

(1) one more electron and a larger radius
(2) one more electron and a smaller radius
(3) one fewer electron and a larger radius
(4) one fewer electron and a smaller radius

36 Which ion in the ground state has the same electron configuration as an atom of neon in the ground state?

(1) K^+
(2) Li^+
(3) F^-
(4) Cl^-

37 Which substance can *not* be broken down by a chemical change?

(1) barium
(2) butanal
(3) methane
(4) methanol

38 The difference in which property allows the separation of a sample of water and sand by using filter paper and a funnel?

(1) boiling point
(2) melting point
(3) particle size
(4) sample volume

39 According to Table *F*, which compound has a very low solubility in water?

(1) sodium carbonate
(2) sodium sulfide
(3) calcium hydroxide
(4) calcium phosphate

40 What is the molarity of a NaOH solution containing 0.125 mole of NaOH in 0.200 L of water?

(1) 0.025 M
(2) 0.250 M
(3) 0.625 M
(4) 1.60 M

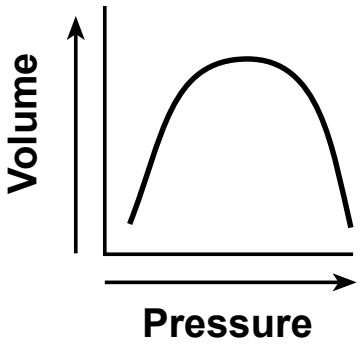
41 Compared to a 0.10 M aqueous $NaNO_3$ solution at 1 atmosphere, a 1.0 M aqueous $NaNO_3$ solution at 1 atmosphere has a

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

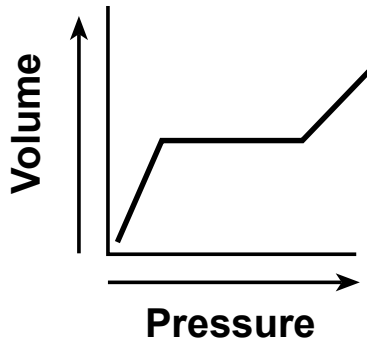
42 What is the temperature, in degrees Celsius, of a sample of matter at 35 K?

(1) −238°C
(2) −308°C
(3) 35°C
(4) 308°C

43 Which graph represents the relationship between pressure and volume for an ideal gas at constant temperature?



(1)



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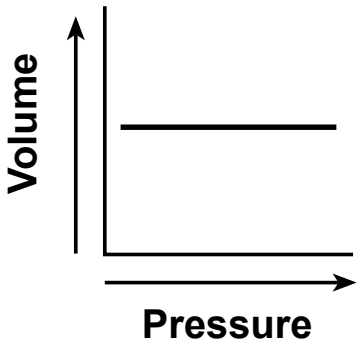

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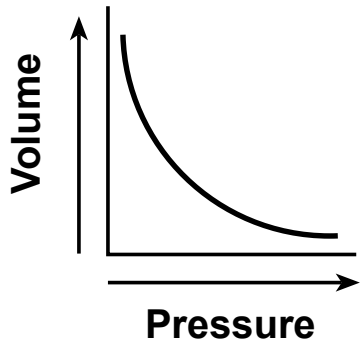


(4)

44 Which equation represents a physical change?

(1) $H_2(g) + I_2(g) \rightarrow 2HI(g)$
(2) $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$
(3) $I_2(s) \rightarrow I_2(g)$
(4) $3O_2(g) \rightarrow 2O_3(g)$

45 Which combination of reactants would result in the fastest reaction rate?

(1) a 1.0 g strip of zinc with 10 mL of 0.20 M HCl(aq)
(2) a 1.0 g strip of zinc with 10 mL of 2.0 M HCl(aq)
(3) 1.0 g of powdered zinc with 10 mL of 0.20 M HCl(aq)
(4) 1.0 g of powdered zinc with 10 mL of 2.0 M HCl(aq)

46 Which equation represents a redox reaction?

(1) $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(\ell)$
(2) $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$
(3) $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
(4) $NaOH(aq) + HBr(aq) \rightarrow H_2O(\ell) + NaBr(aq)$

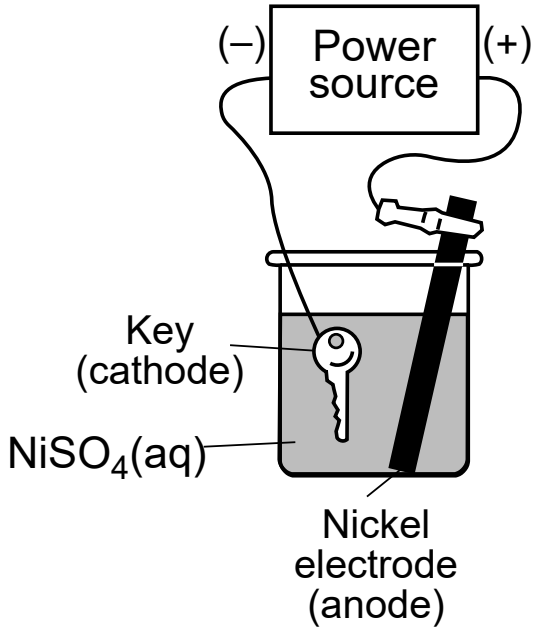
47 Which equation represents a reduction half-reaction?

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

48 The pH value of a solution is changed from 6.0 to 4.0. Which phrase describes the change in the hydronium ion concentration of the solution?

(1) decreased by a factor of 2
(2) increased by a factor of 2
(3) decreased by a factor of 100
(4) increased by a factor of 100

49 A key is plated with nickel as shown in the diagram below.



Which type of cell is represented by the diagram and what change occurs?

(1) electrolytic cell; electrical energy produces a chemical change
(2) electrolytic cell; a chemical change produces electrical energy
(3) voltaic cell; electrical energy produces a chemical change
(4) voltaic cell; a chemical change produces electrical energy

50 Which equation represents a nuclear fusion reaction?

(1) ${}^{87}_{37}\mathrm{Rb} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{87}_{38}\mathrm{Sr}$

(2) ${}^{11}_{6}\mathrm{C} \rightarrow {}^{0}_{+1}\mathrm{e} + {}^{11}_{5}\mathrm{B}$

(3) ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$

(4) ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3{}^{1}_{0}\mathrm{n}$

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 molecular formula for a compound that has the empirical formula CH_2O and a molar mass of 180. grams per mole. [1]

Base your answers to questions 52 through 54 on the information below and on your knowledge of chemistry.

Bromine, chlorine, fluorine, and iodine are four elements in Group 17 that can be differentiated by some of their properties.

52 State the trend in atomic radius for these four elements as they are considered in order of increasing atomic number. [1]

53 Determine the mass of a sample of iodine that has a volume of 2.5 cm^3 at room temperature and standard pressure. [1]

54 State, in terms of electrons, why these elements have similar chemical properties. [1]

Base your answers to questions 55 and 56 on the information below and on your knowledge of chemistry.

When solid calcium carbonate is heated, solid calcium oxide and carbon dioxide gas are formed. The balanced equation below represents this reaction.

$$CaCO_3(s) + \text{energy} \rightarrow CaO(s) + CO_2(g)$$

55 State the molecular polarity of a CO_2 molecule. [1]

56 Based on Table *S*, determine the electronegativity difference between oxygen and calcium in calcium oxide. [1]

GO RIGHT ON TO THE NEXT PAGE ⇨

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

During a laboratory activity, a student dissolves 20.0 grams of solid ammonium chloride, $NH_4Cl(s)$, in 100.0 grams of water at 25°C. After thorough stirring, no undissolved $NH_4Cl(s)$ remains. During this laboratory activity, appropriate safety equipment is used and safety procedures are followed.

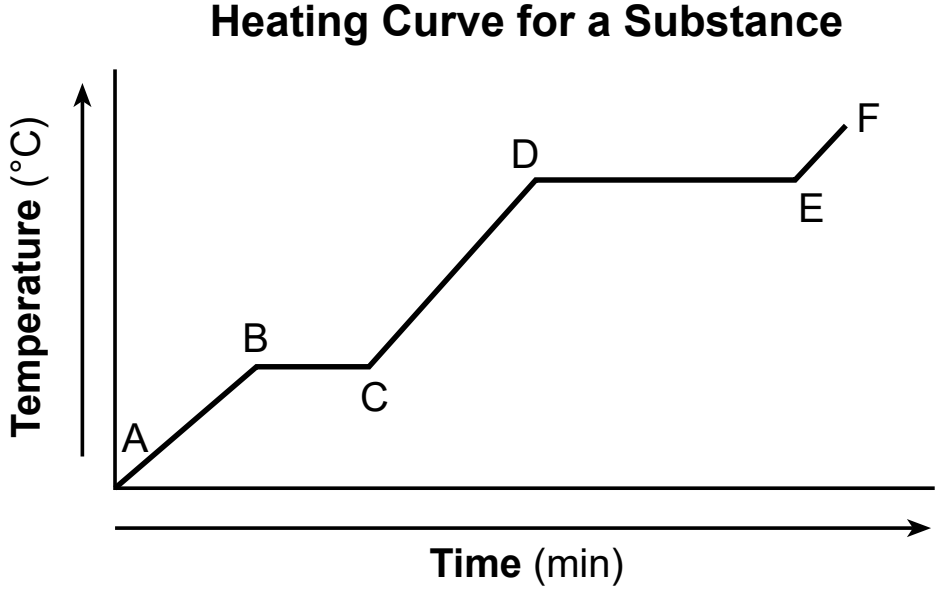
57 Classify, in terms of saturation, the type of solution produced. [1]

58 State evidence from Table *I* that indicates that this dissolving process is endothermic. [1]

59 State, in terms of particle distribution, why this solution is classified as a homogeneous mixture. [1]

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

Starting as a solid, a sample of a substance is heated uniformly at standard pressure, as shown by the heating curve below.



60 Identify the interval during which the average distance between the particles is the greatest. [1]

61 State what happens to the potential energy of the particles during the melting of the substance. [1]

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

A 30.0-milliliter sample of HCl(aq) was exactly neutralized by 18.0 milliliters of 0.10 M KOH(aq). During this laboratory activity, appropriate safety equipment was used and safety procedures were followed.

62 State the color of bromcresol green indicator if it were added to a sample of the 0.10 M KOH(aq). [1]

63 State the number of significant figures used to express the concentration of KOH(aq). [1]

64 Determine the concentration of the HCl(aq) sample, using the titration data. [1]

65 Compare the hydroxide ion concentration of the 0.10 M KOH(aq) with the hydroxide ion concentration of the resulting neutral solution. [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.

Some scientists study samples of ancient ice. A water molecule trapped in ancient ice typically has an oxygen-16 or an oxygen-18 in its structure. Water with oxygen-16 evaporates slightly faster from seawater than water with oxygen-18. The three naturally occurring isotopes of oxygen have mass numbers of 16, 17, or 18.

66 Compare the number of protons to the number of electrons in an atom of oxygen-18. [1]

67 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for an atom of oxygen. [1]

68 State, in terms of neutrons, why a water molecule containing an O-18 atom has a greater mass than a water molecule containing an O-16 atom. [1]

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

The table below shows two compounds and their uses.

Compound	Use
KO_2	as a source of $O_2(g)$ in space shuttles
$NaHCO_3$	as a source of $CO_2(g)$ in baking

Potassium superoxide, KO_2, removes carbon dioxide from the air and produces oxygen in space shuttles, as represented in balanced equation 1 below.

Equation 1: $4KO_2(s) + 2CO_2(g) \rightarrow 2K_2CO_3(s) + 3O_2(g) + \text{energy}$

The heating of sodium hydrogen carbonate, $NaHCO_3$, causes baked goods to rise when it produces steam and carbon dioxide gas, as shown in unbalanced equation 2 below.

Equation 2: $NaHCO_3(s) + \text{heat} \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$

69 Show a numerical setup for calculating the percent composition by mass of oxygen in the sodium hydrogen carbonate (gram-formula mass = 84 g/mol). [1]

70 Determine the number of moles of K_2CO_3 produced when 3.50 moles of KO_2 completely reacts, as represented in equation 1. [1]

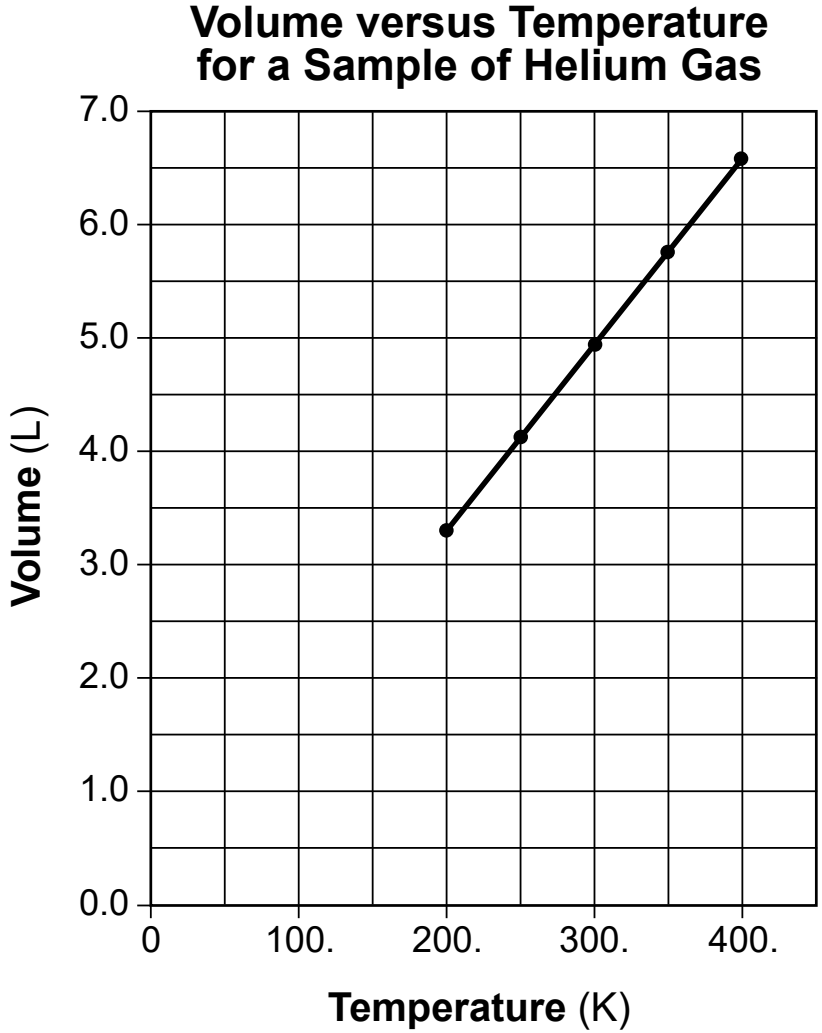
71 Balance equation 2 *in your answer booklet* for the heating of $NaHCO_3(s)$, using smallest whole-number coefficients. [1]

GO RIGHT ON TO THE NEXT PAGE ⇨

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

In 1787, Jacques Charles, a French scientist and pioneer balloonist, performed experiments on how the volume of a gas depends on temperature.

Using a rigid cylinder with a movable piston containing a sample of helium gas, a scientist obtained data for temperature and volume. The graph below represents the relationship between the temperature and volume of the sample of helium gas at 1.0 atmosphere.



Questions 72 and 73 are continued on the next page.

72 Determine the volume of this sample of helium gas at 350. K. [1]

73 Compare the average kinetic energy of the helium atoms in the sample at 200. K to the average kinetic energy of the helium atoms at 300. K. [1]

GO RIGHT ON TO THE NEXT PAGE ⇨

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

In the early 1900s, scientists developed a process to produce ammonia from hydrogen and atmospheric nitrogen on an industrial scale. The balanced equation below represents this reaction.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 91.8\ kJ$$

At room temperature, the reaction occurs at a very slow rate. Therefore, this process takes place in a special reaction vessel at high temperature and high pressure. A catalyst is used to increase the rate of the production of ammonia. The reaction gases are cooled to remove the ammonia as a liquid and the remaining gases are sent back to the reaction vessel.

74 Explain, in terms of collision theory, why reacting hydrogen and nitrogen at high temperature increases the rate of the reaction. [1]

75 Determine the net quantity of heat released when 1.0 mole of ammonia gas, $NH_3(g)$, is produced by this reaction. [1]

76 Using the axes *in your answer booklet*, draw a potential energy diagram for the reaction. [1]

77 State, in terms of activation energy and reaction pathway, why the addition of a catalyst increases the rate of production of ammonia. [1]

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

In a laboratory activity, a student reacts an organic acid with an alcohol and produces a compound with a distinct odor. The incomplete equation below shows the reaction in the laboratory activity with a missing product, *X*.

$$\underset{\text{Reactant 1}}{CH_3COOH} + \underset{\text{Reactant 2}}{CH_3CH_2OH} \rightarrow CH_3COOCH_2CH_3 + X$$

During the laboratory activity, appropriate safety equipment is used and safety procedures are followed.

78 Identify the element present in the reactants that allows them to be classified as organic compounds. [1]

79 Write a chemical name for reactant 1. [1]

80 Write a formula for the missing product, *X*, in the equation. [1]

81 Identify the class of organic compounds to which $CH_3COOCH_2CH_3$ belongs. [1]

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

Radioactive isotopes are used in a variety of ways. Several isotopes and their uses are shown below.

Radioactive Isotopes and Their Uses

Isotope	Use
Fe-59	anemia diagnosis
I-131	thyroid function diagnosis
U-238	dating geological formations
Am-241	smoke detectors

82 Compare the penetrating power of the beta particle emitted from the I-131 nuclide to the penetrating power of the alpha particle emitted from the U-238 nuclide. [1]

83 Complete the nuclear equation, *in your answer booklet*, for the decay of the Fe-59 used to diagnose anemia disorders, by writing a notation for the missing product. [1]

84 Determine the fraction of an original sample of the radioactive isotope used to test for thyroid problems that remains unchanged after 24.063 days. [1]

85 Determine the number of neutrons in an atom of Am-241. [1]

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