The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
CHEMISTRY

Thursday, June 16, 2022 — 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 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 subatomic particles are matched with their charges?

(1) Protons are positive and neutrons are negative.
(2) Protons are positive and electrons are negative.
(3) Protons are negative and neutrons have no charge.
(4) Protons are negative and electrons have no charge.

2 Which conclusion directly resulted from the "gold foil experiment"?

(1) Atoms are mostly empty space.
(2) Atoms are hard, indivisible spheres.
(3) Electrons are located in shells.
(4) Electrons have a small mass.

3 The bright-line spectrum of an element is produced when excited-state electrons

(1) absorb energy and move to higher energy states
(2) absorb energy and move to lower energy states
(3) release energy and move to higher energy states
(4) release energy and move to lower energy states

4 The elements on the Periodic Table of the Elements are arranged in order of increasing

(1) atomic mass
(2) atomic number
(3) mass number
(4) oxidation state

5 Atoms of which element in Group 15 have the greatest electronegativity?

(1) As
(2) Bi
(3) N
(4) P

6 Which term represents the simplest whole-number ratio of atoms of the elements in a compound?

(1) atomic mass
(2) formula mass
(3) empirical formula
(4) structural formula

7 How many electrons are shared in a triple bond between two atoms?

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

8 Given the equation representing a reaction:

$$Cl_2 \rightarrow Cl + Cl$$

What occurs during this reaction?

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

9 Krypton atoms in the ground state tend *not* to bond with other atoms because their

(1) second electron shell contains eight electrons
(2) third electron shell contains eighteen electrons
(3) innermost electron shell contains two electrons
(4) outermost electron shell contains eight electrons

10 All matter can be classified as

(1) an element
(2) a compound
(3) a mixture or an element
(4) a mixture or a substance

11 Which sample at STP has the same chemical properties as 10. grams of Al(s) at STP?

(1) 10. grams of Si(s)
(2) 10. grams of Na(s)
(3) 5 grams of Al(s)
(4) 5 grams of Mg(s)

12 Which sample of matter can *not* be broken down by a chemical change?

(1) antimony
(2) ethanol
(3) methane
(4) water

13 Based on Table *F*, which 10.-gram sample, when thoroughly mixed with 1 liter of water at room temperature, forms a heterogeneous mixture?

(1) ammonium chloride, NH_4Cl
(2) potassium iodide, KI
(3) silver bromide, AgBr
(4) sodium nitrate, $NaNO_3$

14 Compared to a 1.0 M NaCl(aq) solution at 1.0 atm, a 2.0 M NaCl(aq) solution at 1.0 atm has

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

15 Which list includes three forms of energy?

(1) temperature, chemical, thermal
(2) temperature, thermal, alkalinity
(3) electromagnetic, nuclear, chemical
(4) electromagnetic, alkalinity, nuclear

16 Under which conditions of pressure and temperature is a real gas most like an ideal gas?

(1) low pressure and low temperature
(2) low pressure and high temperature
(3) high pressure and low temperature
(4) high pressure and high temperature

17 Which sample of argon gas has the same number of atoms as a 100.-milliliter sample of helium gas at 1.0 atm and 300. K?

(1) 50. mL at 1.0 atm and 300. K
(2) 50. mL at 0.5 atm and 300. K
(3) 100. mL at 0.5 atm and 300. K
(4) 100. mL at 1.0 atm and 300. K

18 Which process is a chemical change?

(1) condensation of $H_2O(g)$
(2) synthesis of MgO(s)
(3) evaporation of $C_2H_5OH(\ell)$
(4) sublimation of $CO_2(s)$

19 Which property is determined by the structure, arrangement, and interactions of the molecules of a substance at a given temperature and pressure?

(1) atomic radius
(2) half-life
(3) formula mass
(4) physical state

20 A collision between reactant particles is most likely to result in a reaction when the particles have proper orientation and proper

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

21 Given the equation representing a system at equilibrium:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

Which statement describes this reaction at equilibrium?

(1) The concentration of the reactant and the product must be equal.
(2) The concentration of the reactant and the product must be constant.
(3) The rates of the forward and reverse reactions are increasing.
(4) The rates of the forward and reverse reactions are decreasing.

22 Which phrase describes the effect of adding a catalyst to a chemical reaction in order to increase the reaction rate?

(1) provides a different reaction pathway with a lower activation energy
(2) provides a different reaction pathway with a higher activation energy
(3) uses the same reaction pathway with a higher activation energy
(4) uses the same reaction pathway with a lower activation energy

23 Systems in nature tend to undergo changes 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 element must be present in an organic compound?

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

25 Which formula represents a saturated hydrocarbon?

(1) C_2H_2
(2) C_2H_4
(3) C_6H_{10}
(4) C_6H_{14}

26 Which reaction occurs at the anode in an electrochemical cell?

(1) saponification
(2) oxidation
(3) esterification
(4) reduction

27 Which statement describes the two types of reactions that occur in operating electrochemical cells?

(1) Nonspontaneous reactions occur in voltaic cells, and spontaneous reactions occur in electrolytic cells.
(2) Nonspontaneous reactions occur in electrolytic cells, and nonspontaneous reactions occur in voltaic cells.
(3) Spontaneous reactions occur in voltaic cells, and nonspontaneous reactions occur in electrolytic cells.
(4) Spontaneous reactions occur in electrolytic cells, and spontaneous reactions occur in voltaic cells.

28 Which term describes an acid according to one acid-base theory?

(1) H^+ acceptor
(2) H^+ donor
(3) H_2 acceptor
(4) H_2 donor

29 Which emission will be released from an unstable Fe-53 nucleus?

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

30 What is a potential risk associated with radioactive isotopes?

(1) biological exposure
(2) curing of diseases
(3) industrial measurements
(4) tracing chemical processes

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 electrons of a phosphorus atom in an excited state?

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

32 A 26.7-gram sample of which element has a volume of 3.00 cubic centimeters at room temperature?

(1) Cr (3) Nb
(2) Cd (4) Ni

33 Which element is a nonmetal and solid at STP?

(1) lead (3) sodium
(2) nitrogen (4) sulfur

34 What is the molecular formula for $CH_3CH_2COOCH_3$?

(1) C_2H_4O (3) C_4H_8O
(2) $C_2H_4O_2$ (4) $C_4H_8O_2$

35 A substance conducts electricity in the liquid phase but *not* in the solid phase. This substance can be classified as

(1) covalent (3) metallic
(2) ionic (4) molecular

36 A student measured the melting point of a sample of gallium to be 309 K. Based on Table *S*, which numerical setup can be used to calculate the student's percent error?

(1) $\frac{309\,\text{K} - 303\,\text{K}}{303\,\text{K}} \times 100$ (3) $\frac{303\,\text{K}}{309\,\text{K}} \times 100$

(2) $\frac{309\,\text{K} - 303\,\text{K}}{309\,\text{K}} \times 100$ (4) $\frac{309\,\text{K}}{303\,\text{K}} \times 100$

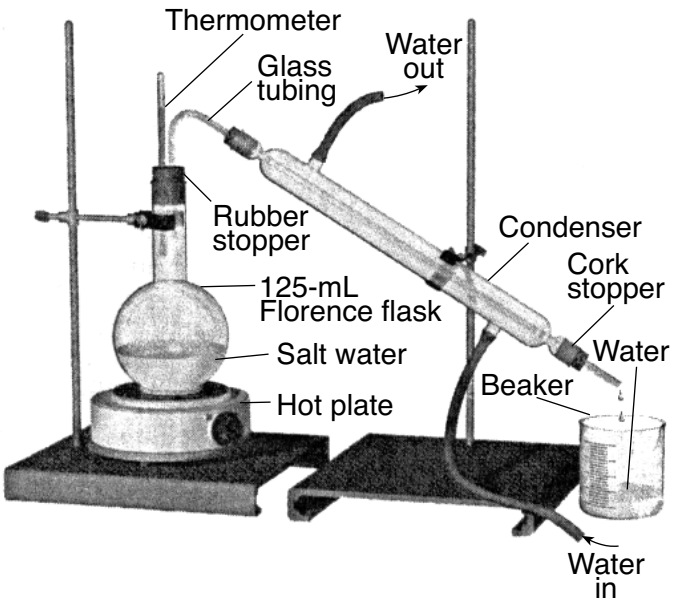
37 Which chemical bond is most polar?

(1) a O–H bond in H_2O
(2) a S–H bond in H_2S
(3) a Se–H bond in H_2Se
(4) a Te–H bond in H_2Te

38 What is the amount of heat required to melt 43 grams of solid magnesium oxide at its melting point? The heat of fusion is 1.9×10^3 J/g.

(1) 2.3×10^{-2} J (3) 8.2×10^4 J
(2) 4.4×10^1 J (4) 3.4×10^5 J

39 Given the diagram of a laboratory apparatus:



This apparatus is used for which process?

(1) filtration (3) chromatography
(2) distillation (4) electrolysis

40 Solid aluminum has a specific heat capacity of 0.90 J/g•K. How many joules of heat are absorbed to raise the temperature of 24.0 grams of aluminum from 300. K to 350. K?

(1) 22 J
(2) 45 J
(3) 1100 J
(4) 1200 J

41 Based on Table *G*, which solute sample in 100.g of water at 40.°C can produce a solution equilibrium in a closed system?

(1) 10. g $KClO_3$
(2) 25 g NaCl
(3) 45 g KCl
(4) 55 g KNO_3

42 Given the equation representing a system at equilibrium:

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

Which change favors the forward reaction?

(1) increasing the concentration of $O_2(g)$
(2) increasing the temperature
(3) decreasing the pressure
(4) decreasing the concentration of $SO_2(g)$

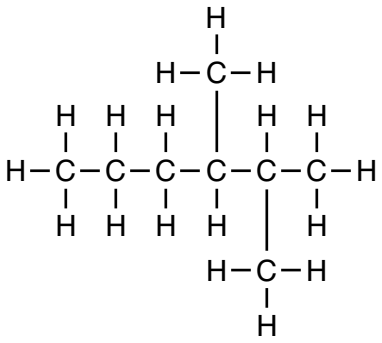
43 When ice, $H_2O(s)$, melts at 0°C, entropy increases because the

(1) average kinetic energy of the particles increases
(2) average kinetic energy of the particles decreases
(3) particle arrangement is more random
(4) particle arrangement is less random

44 At STP, propanal and propanone have different chemical properties due to their different

(1) molecular masses
(2) empirical formulas
(3) percent compositions
(4) functional groups

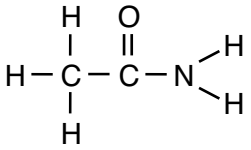
45 Given the formula for a compound:



What is the IUPAC name of the compound?

(1) 2,3-dimethyloctane
(2) 2,3-dimethylhexane
(3) 4,5-dimethyloctane
(4) 4,5-dimethylhexane

46 Given the formula representing a compound:



This compound is classified as an

(1) amide
(2) amine
(3) ester
(4) ether

47 Which substance is an electrolyte?

(1) H_2
(2) HCl
(3) C_6H_{14}
(4) $C_6H_{12}O_6$

48 An indicator is added to an aqueous solution with a pH value of 5.6. Which indicator is paired with its observed color in this solution?

(1) Methyl orange is yellow.
(2) Phenolphthalein is pink.
(3) Bromcresol green is yellow.
(4) Thymol blue is blue.

49 Solution *A* has a pH value of 2.0 and solution *B* has a pH value of 4.0. How many times greater is the hydronium ion concentration in solution *A* than the hydronium ion concentration in solution *B*?

(1) 10
(2) 2
(3) 100
(4) 4

50 Which net change occurs in both nuclear fission and nuclear fusion reactions?

(1) Mass is converted to energy.
(2) Energy is converted to mass.
(3) Small nuclei form a larger nucleus.
(4) A large nucleus forms smaller nuclei.

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 through 53 on the information below and on your knowledge of chemistry.

The two naturally occuring isotopes of lithium are Li-6 and Li-7. The table below shows the atomic mass and percent natural abundance for these isotopes.

Naturally Occurring Isotopes of Lithium

Isotope	Atomic Mass (u)	Natural Abundance (%)
Li-6	6.015	7.59
Li-7	7.016	92.41

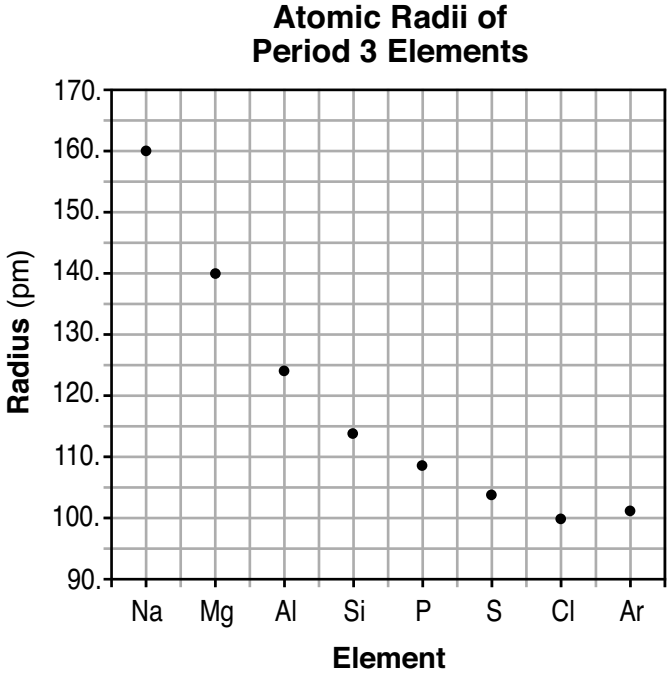
51 State the number of electrons in an atom of Li-7. [1]

52 Compare the energy of an electron in the first shell of a lithium atom to the energy of an electron in the second shell of the same atom. [1]

53 Show a numerical setup for calculating the atomic mass of the element lithium. [1]

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

The graph below represents the atomic radii of the elements in Period 3 on the Periodic Table of the Elements.



54 State the general trend for the atomic radius of the first seven elements in Period 3 when considered in order from left to right. [1]

55 State, in terms of valence electrons, why aluminum and sulfur have different chemical properties. [1]

56 Identify the element in Period 3 that reacts with oxygen to form an ionic compound represented by X in the formula X_2O. [1]

Base your answers to questions 57 and 58 on the information below and on your knowledge of chemistry.

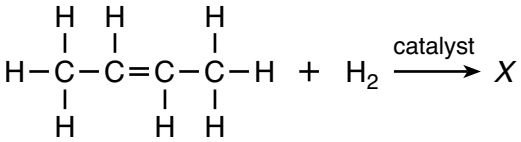
Lithium, beryllium, boron, and fluorine are four elements in Period 2 on the Periodic Table.

57 State, in terms of electrons, why the radius of a Be^{2+} ion is smaller than the radius of a Be atom. [1]

58 Draw a Lewis electron-dot diagram for an atom of boron. [1]

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

The incomplete equation below represents a reaction between 2-butene and hydrogen in the presence of a catalyst, producing one compound, *X*.



59 Explain, in terms of molecular formulas and structural formulas, why 1-butene is an isomer of 2-butene. [1]

60 Draw a structural formula for the missing product, *X*, in the equation. [1]

Base your answers to questions 61 through 65 on the information below and on your knowledge of chemistry.

In a titration using a pH meter, 16.0 milliliters of 0.18 M NaOH(aq) exactly neutralizes a 24.0-milliliter sample of HCl(aq) in a flask. During this laboratory activity, appropriate safety equipment was used and safety procedures were followed.

61 State the number of significant figures used to express the volume of the HCl(aq) solution. [1]

62 Identify the negative ion in the NaOH(aq) used in the titration. [1]

63 Compare the number of moles of hydronium ions to the number of moles of hydroxide ions in the titration mixture when the HCl(aq) is exactly neutralized by the NaOH(aq). [1]

64 Complete the equation *in your answer booklet* for the neutralization reaction by writing a formula for each product. [1]

65 Determine the molarity of the HCl(aq) sample based on the titration data. [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 70 on the information below and on your knowledge of chemistry.

An average person on board the International Space Station (ISS) requires 840 grams of oxygen per day. To produce the oxygen needed on the ISS, water undergoes an electrolysis reaction. The oxygen produced is vented into the ISS cabin, and the hydrogen is vented into outer space. The reaction is represented by the balanced equation below.

$$2H_2O(\ell) + \text{energy} \rightarrow 2H_2(g) + O_2(g)$$

Some gases in the ISS must be removed from the air the astronauts breathe. Carbon dioxide can be removed using solid lithium hydroxide.

66 Show a numerical setup for calculating the number of moles of oxygen gas required for the average person per day. The gram-formula mass of $O_2(g)$ is 32 g/mol. [1]

67 State the change in oxidation number for oxygen during the electrolysis reaction represented by the equation. [1]

68 Determine the number of moles of oxygen vented into the cabin when 120 moles of water undergoes electrolysis. [1]

69 Determine the percent composition by mass of hydrogen in water. [1]

70 Balance the equation for the reaction between LiOH and CO_2 *in your answer booklet*, using the *smallest* whole-number coefficients. [1]

Base your answers to questions 71 through 73 on the information below and on your knowledge of chemistry.

One sample of tap water contains dissolved ions such as $Ca^{2+}(aq)$, $Mg^{2+}(aq)$, and $CO_3^{2-}(aq)$. A 150.-gram sample of this tap water contains 0.000 75 gram of $CaCO_3(aq)$. When these ions in the tap water are present in greater concentrations, the water is called hard water. The hard water can damage water pipes and water heaters by producing large deposits of solid calcium carbonate, known as scale. Some homeowners have a water softener to replace positive ions, such as $Ca^{2+}(aq)$ and $Mg^{2+}(aq)$, in hard water with sodium ions, $Na^{+}(aq)$.

71 Determine the parts per million of $CaCO_3$ in the tap water sample. [1]

72 State, in terms of aqueous ions, why this tap water can conduct an electric current. [1]

73 Using the key *in your answer booklet*, draw *at least two* water molecules in the box, showing the orientation of each water molecule toward the Ca^{2+} ion. [1]

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

A 3% hydrogen peroxide solution, $H_2O_2(aq)$, is commonly used as a disinfectant. Hydrogen peroxide, H_2O_2, decomposes as represented by the balanced equation below.

$$2H_2O_2 \rightarrow 2H_2O + O_2 + \text{heat}$$

74 State evidence, from the equation, that the reaction is exothermic. [1]

75 Explain, in terms of substances, why the reaction is a decomposition reaction. [1]

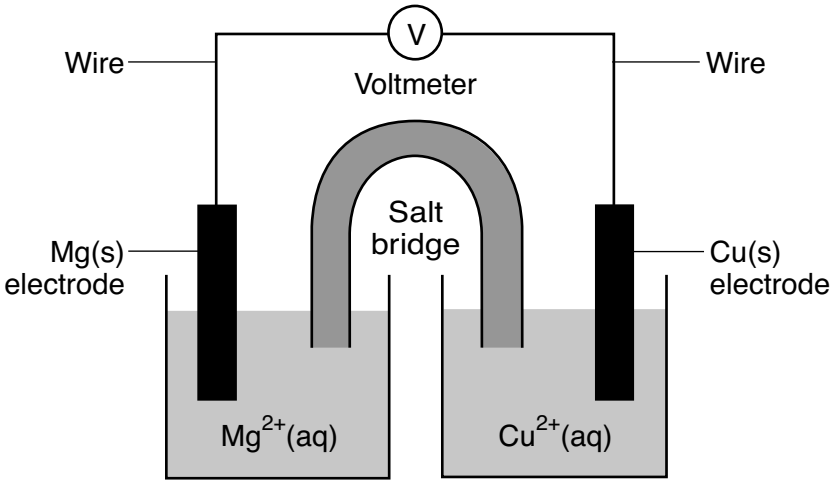
76 State how increasing the temperature of the H_2O_2 affects the rate of the reaction. [1]

77 On the potential energy diagram *in your answer booklet*, draw a double-headed arrow (↕) to indicate the interval that represents the heat of reaction. [1]

Base your answers to questions 78 through 82 on the information below and on your knowledge of chemistry.

During a laboratory activity, appropriate safety equipment is used and safety procedures are followed. A student constructs a voltaic cell with magnesium and copper electrodes. The diagram and net ionic equation below represent this cell and the reaction that occurs.

Voltaic Cell



$$Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$$

78 Identify the subatomic particles that flow through the wire as the cell operates. [1]

79 Compare the number of electrons lost to the number of electrons gained during the reaction in the operating cell. [1]

80 State the form of energy that is converted to electrical energy in the operating cell. [1]

81 Write a balanced equation for the half-reaction that occurs in the copper half-cell when the cell operates. [1]

82 Identify one metal from Table *J* that is more easily oxidized than Mg. [1]

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

Element 117, Uus, has been synthesized and has at least two isotopes, Uus-293 and Uus-294. Atoms of Uus-293 can be made by bombarding Bk-249 with Ca-48 in a reaction represented by the nuclear equation below.

$$^{48}_{20}\text{Ca} + ^{249}_{97}\text{Bk} \rightarrow ^{293}_{117}\text{Uus} + 4\,^{1}_{0}\text{n}$$

The Bk-249 has a half-life of 320. days, decays by beta emission, and also emits gamma rays.

83 Determine the fraction of Bk-249 that remains unchanged after 960. days. [1]

84 State, in terms of *both* protons and neutrons, why Uus-293 and Uus-294 are isotopes of the same element. [1]

85 Complete the nuclear equation *in your answer booklet* for the alpha decay of Uus-294 by writing a notation for the missing product. [1]

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