XIX. Chemistry, High School

High School Chemistry Test

The spring 2008 high school MCAS Chemistry test was based on learning standards in the Chemistry content strand of the Massachusetts *Science and Technology/Engineering Curriculum Framework* (2006). These learning standards appear on pages 69–73 of the *Framework*.

The *Science and Technology/Engineering Curriculum Framework* is available on the Department Web site at www.doe.mass.edu/frameworks/current.html.

In *Test Item Analysis Reports* and on the Subject Area Subscore pages of the MCAS *School Reports* and *District Reports*, Chemistry test results are reported under the following four MCAS reporting categories:

- Atomic Structure and Periodicity
- Bonding and Reactions
- Properties of Matter and Thermochemistry
- Solutions, Equilibrium, and Acid-Base Theory

Test Sessions

The MCAS high school Chemistry test included two separate test sessions, which were administered on consecutive days. Each session included multiple-choice and open-response questions.

Reference Materials and Tools

Each student taking the high school Chemistry test was provided with a Chemistry Formula and Constants Sheet/Periodic Table of the Elements. Copies of both sides of this formula sheet follow the final question in this chapter.

Each student also had sole access to a calculator with at least four functions and a square-root key.

The use of bilingual word-to-word dictionaries was allowed for current and former limited English proficient students only, during both Chemistry test sessions. No other reference tools or materials were allowed.

Cross-Reference Information

The table at the conclusion of this chapter indicates each item's reporting category and the *Framework* learning standard it assesses. The correct answers for multiple-choice questions are also displayed in the table.

Chemistry

SESSION 1

DIRECTIONS

This session contains twenty-one multiple-choice questions and two open-response questions. Mark your answers to these questions in the spaces provided in your Student Answer Booklet. You may work out solutions to multiple-choice questions in the test booklet.

1 Which of the following statements describes a difference between a mixture and a pure substance?

A. A mixture tends to be homogenous, while a pure substance tends to be heterogeneous.

B. A mixture has a specific melting point, while the melting point of a pure substance can vary.

C. The density of a mixture can change with temperature, but the density of a pure substance cannot change.

D. The composition of a mixture can vary from sample to sample, but the composition of a pure substance is always the same.

2 Which of the following pieces of evidence **best** supports Bohr's idea that electrons occupy specific energy levels within an atom?

A. Sodium atoms become positive ions when they lose electrons.

B. Each element emits a unique bright-line spectrum when it falls from an excited state to a ground state.

C. Beryllium atoms bombarded with alpha particles produce beams that are not influenced by magnetic fields.

D. Each element has physical and chemical properties that are unique to that element and different from those of other elements.

3 The air inside a beach ball is at a temperature of 25°C and a pressure of 1.0 atm. If the ball contains 0.85 mol of air, what is its volume?

A. 1.7 L

B. 6.1 L

C. 21 L

D. 27 L

4 In the reaction of hydrobromic acid (HBr) and ammonia (NH_3), ammonia acts as a Brønsted base. Which of the following ions is formed?

A. N^+

B. NH^{2-}

C. NH_2^-

D. NH_4^+

5 Calcium combines with boron, as represented by the chemical equation below.

$$Ca + 6B \rightarrow CaB_6$$

What is the minimum amount of calcium, in grams, that could completely react with 54.0 g of boron?

A. 9.00 g
B. 33.4 g
C. 87.4 g
D. 241 g

6 Which of the following correctly pairs a phase of matter with its description?

A. Solid: Particles have no motion.
B. Liquid: Particles expand to fill any container in which they are placed.
C. Gas: Particles have higher amounts of energy than when in the liquid phase.
D. Liquid: Particles are more strongly attached to one another than when in the solid phase.

7 The industrial preparation of ozone (O_3) uses oxygen gas (O_2), as shown in the equation below.

$$3O_2(g) \xrightarrow{\text{electricity}} 2O_3(g)$$

If 96.0 kg of O_2 gas actually yields 11.5 kg of O_3, what is the percent yield in this reaction?

A. 3.10%
B. 8.35%
C. 12.0%
D. 18.0%

8 Which of the following elements has an electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^1$?

A. lithium
B. aluminum
C. phosphorus
D. calcium

9 During a series of experiments, a chemist found that a particular compound has an empirical formula of C_2H_5 and a molecular mass of 58.12 g/mol. What is the molecular formula of this compound?

A. CH_4
B. C_2H_5
C. C_4H_{10}
D. $C_{18}H_{40}$

10 What is the correct formula for aluminum oxide?

A. AlO_2
B. Al_2O_3
C. Al_3O_2
D. Al_3O_6

11 Which of the following sections of the periodic table contains only metals?

A. group 2
B. group 18
C. period 2
D. period 6

Question 12 is an open-response question.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 12 in the space provided in your Student Answer Booklet.

12 A sample of neon gas has a volume of 12.0 L at standard temperature and pressure (STP).

a. How many moles of neon gas are in the sample? Show your calculations and include units in your answer.

b. How many atoms of neon gas are in the sample? Show your calculations and include units in your answer.

c. Will a sample of argon gas with the same volume at STP contain more moles, fewer moles, or the same number of moles of gas as the neon sample? Explain your answer.

Mark your answers to multiple-choice questions 13 through 22 in the spaces provided in your Student Answer Booklet. Do not write your answers in this test booklet, but you may work out solutions to multiple-choice questions in the test booklet.

13 A balanced equation is shown below.

$$C_6H_{12}O_6(l) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$$

Which of the following statements correctly compares the mass of the reactant with the mass of the products in this equation?

A. The mass of the reactant is half the mass of the products.

B. The mass of the reactant is twice the mass of the products.

C. The mass of the reactant is one-fourth the mass of the products.

D. The mass of the reactant is the same as the mass of the products.

14 An insect known as a water strider can walk across the surface of a pond. Which of the following is directly responsible for this insect being able to walk on the surface without sinking?

A. ionic bonding

B. oxygen bonding

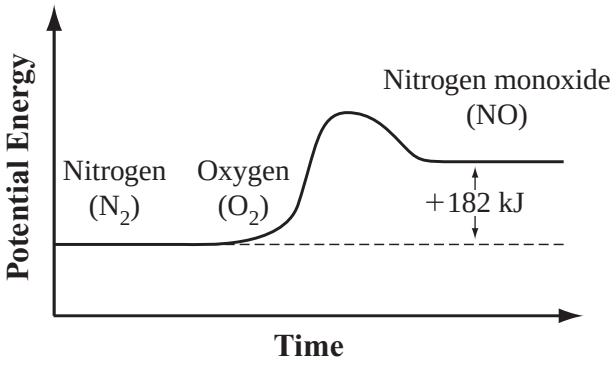
C. hydrogen bonding

D. nonpolar covalent bonding

15 The equation below shows the formation of nitrogen monoxide.

$$N_2 + O_2 + \text{energy} \rightarrow 2NO$$

The graph below shows how potential energy changes as nitrogen and oxygen react to form nitrogen monoxide.



Which of the following conclusions about the reaction is supported by this graph?

A. It is an exothermic reaction.

B. It is an endothermic reaction.

C. It is a decomposition reaction.

D. It is a single displacement reaction.

16 A person left a bottle of distilled water and a bottle of a sugary drink outside overnight. In the morning, one liquid was frozen but the other was not.

Which liquid was frozen and why did it freeze?

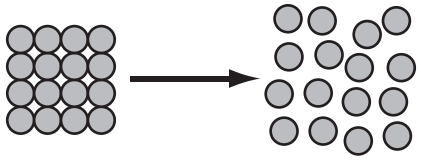
A. The sugary drink froze because solutions are more dense than pure substances.

B. The distilled water froze because pure substances are more dense than solutions.

C. The sugary drink froze because solutions have a higher freezing point than pure substances.

D. The distilled water froze because pure substances have a higher freezing point than solutions.

17 The diagram below represents a phase change for some copper atoms.



Which of the following phase changes are the copper atoms undergoing?

A. gas to liquid

B. liquid to gas

C. solid to liquid

D. liquid to solid

18 Which of the following characteristics of an element can be determined precisely by considering **only** the element's specific position on the periodic table?

A. radius of each ion

B. density of the solid

C. boiling point of the liquid

D. number of protons in each atom

19 The Lewis dot structure shown below represents an atom of an unknown metallic element M.

M•

When atoms of this unknown metal react with oxygen, a compound is formed. Which of the following is the **most likely** chemical formula of the resulting metal oxide?

A. MO

B. MO_2

C. M_2O

D. M_2O_3

20 The pH of four different solutions of common materials is measured. Which of the following lists the solutions in order from most acidic to most basic?

A. battery acid, lemon juice, blood, laundry detergent

B. lemon juice, battery acid, blood, laundry detergent

C. laundry detergent, blood, lemon juice, battery acid

D. battery acid, blood, laundry detergent, lemon juice

21 Which of the following statements explains why the bond in hydrogen chloride (HCl) is polar covalent?

A. The atomic mass of chlorine is greater than that of hydrogen.

B. The electronegativity of chlorine is greater than that of hydrogen.

C. The diameter of a chlorine atom is greater than that of a hydrogen atom.

D. The number of valence electrons in a chlorine atom is greater than that in a hydrogen atom.

22 Calcium hydroxide, $Ca(OH)_2$, is used as a soil conditioner in home gardens. When mixed with water, it releases hydroxide ions.

Which of the following is the **most likely** pH for a solution of calcium hydroxide and water?

A. 1

B. 3

C. 7

D. 10

Question 23 is an open-response question.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 23 in the space provided in your Student Answer Booklet.

23 Large helium-filled balloons are used to carry instruments to altitudes high above Earth's surface. These balloons are used to collect data related to Earth's atmosphere.

a. As the balloons rise to higher altitudes, the atmospheric pressure decreases. Describe changes in the balloons' volumes resulting from the decrease in atmospheric pressure.

b. Temperature also varies with altitude. Describe how a decrease in temperature will tend to affect the volumes of the balloons.

c. A balloon may eventually reach an elevation where the density of the atmosphere is equal to the density of the balloon and the balloon will not rise any higher. Based on your responses to parts (a) and (b), how could the maximum altitude of a helium balloon be increased?

You may use graphs, diagrams, or equations in your answers.

Chemistry

SESSION 2

DIRECTIONS

This session contains nineteen multiple-choice questions and three open-response questions. Mark your answers to these questions in the spaces provided in your Student Answer Booklet. You may work out solutions to multiple-choice questions in the test booklet.

24 Magnesium has two valence electrons. Oxygen has six valence electrons. What is the correct chemical formula for magnesium oxide?

A. MgO

B. MgO_2

C. Mg_2O

D. Mg_2O_3

25 Which of the following samples of sugar will dissolve **fastest** in a pitcher of lemonade?

A. 5 g of cubed sugar in 5°C lemonade

B. 5 g of cubed sugar in 20°C lemonade

C. 5 g of granulated sugar in 5°C lemonade

D. 5 g of granulated sugar in 20°C lemonade

26 The formula for carbonic acid is H_2CO_3, and the formula for hydrogen carbonate is HCO_3^-. Together they form a buffer that is found in blood.

Which of the following reactions represents what happens when excess base enters the bloodstream?

A. $HCO_3^-(aq) + H_3O^+(aq) \rightarrow H_2CO_3(aq) + H_2O(l)$

B. $H_2CO_3(aq) + OH^-(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$

C. $HCO_3^-(aq) + H_2O(l) \rightarrow H_2CO_3(aq) + OH^-(aq)$

D. $H_2CO_3(aq) + H_2O(l) \rightarrow HCO_3^-(aq) + H_3O^+(aq)$

27 Different amounts of ammonia gas (NH_3) and hydrogen chloride gas (HCl) are combined in the laboratory. Some of the masses of the reactants and the products for two trials are shown below.

Experimental Masses of Ammonia and Hydrogen Chloride

Trial	Mass NH_3	Mass HCl	Mass NH_4Cl
1	3.40 g	7.30 g	10.70 g
2	?	?	32.10 g

Based on the law of constant composition, which of the following values correctly replace the question marks in the table?

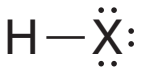
A. 6.42 g of NH_3 and 25.68 g of HCl

B. 8.50 g of NH_3 and 18.25 g of HCl

C. 10.20 g of NH_3 and 21.90 g of HCl

D. 16.05 g of NH_3 and 16.05 g of HCl

28 The Lewis dot structure of a compound is shown below.



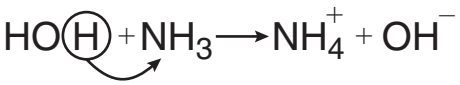
Which of the following elements does X represent in the structure?

A. carbon (C)
B. nitrogen (N)
C. oxygen (O)
D. fluorine (F)

29 Which of the following comparisons correctly describes subatomic particles?

A. An electron has a negative charge and a mass larger than the mass of a proton.
B. A neutron has a negative charge and a mass smaller than the mass of a proton.
C. A neutron has a neutral charge and a mass larger than the mass of an electron.
D. A proton has a positive charge and a mass smaller than the mass of an electron.

30 A chemical equation representing the reaction of water (HOH) and ammonia (NH_3) is shown below.



Which of the following statements **best** explains the chemical action of the reactants in this equation?

A. Both water and ammonia are acting as acids.
B. Both water and ammonia are acting as bases.
C. Water is acting as an acid, and ammonia is acting as a base.
D. Water is acting as a base, and ammonia is acting as an acid.

31 One way that mixtures differ from pure substances is in the methods that can be used to separate them into their components.

Which of the following is a method used to separate the components of some mixtures?

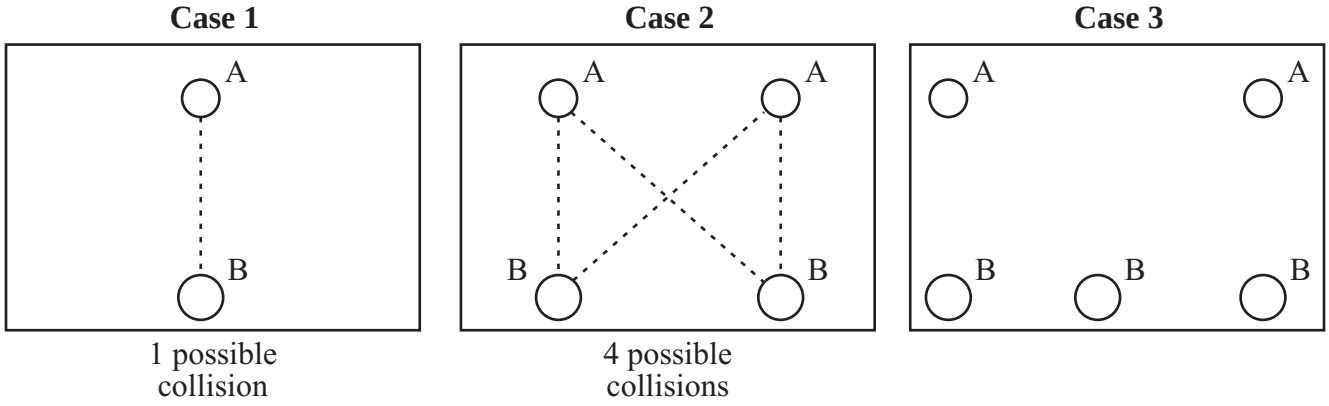
A. a nuclear reaction
B. a filtration process
C. a chemical reaction
D. an electrolysis process

Question 32 is an open-response question.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 32 in the space provided in your Student Answer Booklet.

32 Chemical reactions are thought to result from collisions between reactant particles. One theory of chemical reactions charts the number of possible collisions between the reactant particles present in a sample. The diagrams below show three possible combinations of two elements, A and B, that must collide in order to react. The dashed lines in the first two cases represent potential collisions between A and B.



a. In case 3, how many possible collision combinations can occur between type A and type B particles?

b. Using information from the diagrams above, explain the relationship between reactant concentration and reaction rate.

Mark your answers to multiple-choice questions 33 through 43 in the spaces provided in your Student Answer Booklet. Do not write your answers in this test booklet, but you may work out solutions to multiple-choice questions in the test booklet.

33 Which of the following describes the separation of the components of a mixture?

A. Water is broken down into hydrogen and oxygen.

B. Salt is isolated from seawater through evaporation.

C. Propane reacts with oxygen to form carbon dioxide and water.

D. Calcium carbonate decomposes to form calcium oxide and carbon dioxide.

34 Uranium forms thorium and helium, as shown in the equation below.

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

Which of the following does this equation represent?

A. decomposition reaction

B. physical change

C. radioactive decay

D. synthesis reaction

35 Which of the following elements has the greatest electronegativity?

A. hydrogen (H)

B. fluorine (F)

C. astatine (At)

D. francium (Fr)

36 Which of the following statements accurately describes alpha particles in terms of charge and mass?

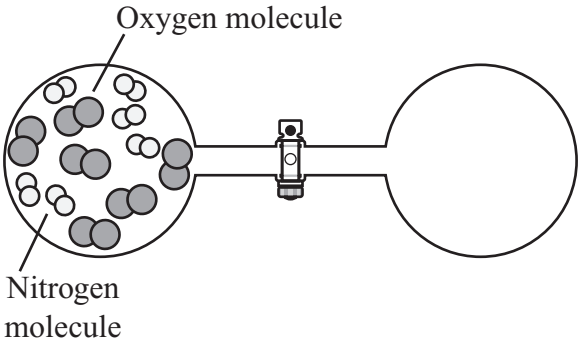
A. Alpha particles are positively charged and less massive than beta particles.

B. Alpha particles are negatively charged and less massive than beta particles.

C. Alpha particles are positively charged and more massive than beta particles.

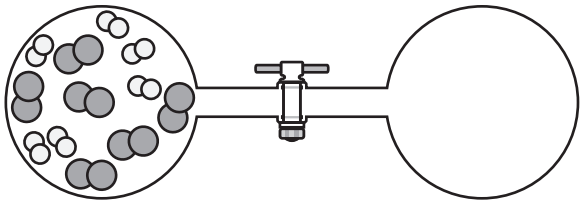
D. Alpha particles are negatively charged and more massive than beta particles.

37 Oxygen (O_2) and nitrogen (N_2) molecules are contained in a flask, which is separated from a second flask by a closed valve, as shown below. The second flask, of equal volume, is a vacuum.

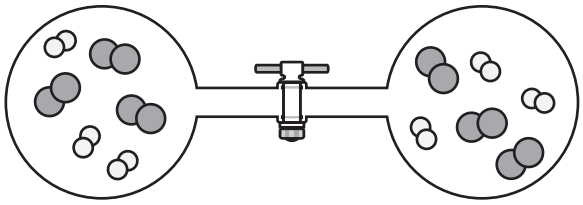


The valve separating the two flasks is opened. Which of the following diagrams represents the **most likely** arrangement of molecules after the valve is opened?

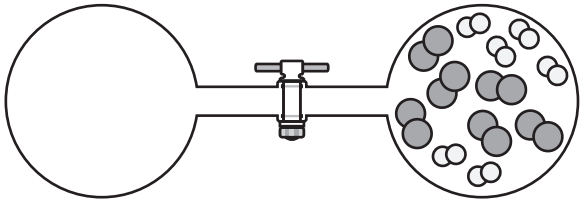
A.



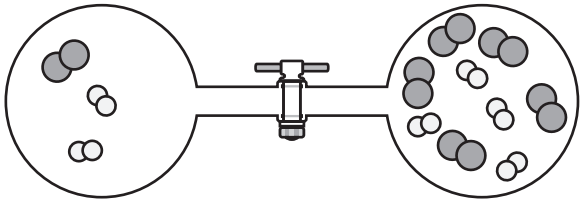
C.



B.



D.



38 A gas enters a compressor where it is converted to a liquid. Which of the following happens to the gas as it becomes a liquid?

A. It loses mass.
B. It releases heat.
C. It loses protons.
D. It releases electricity.

39 Which of the following examples is evidence of a physical change?

A. Ice cream melts in a bowl.
B. A silver spoon tarnishes over time.
C. An electrical current splits water into hydrogen and oxygen.
D. A person inhales oxygen and exhales carbon dioxide and water.

40 An equation is shown below.

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He}$$

Which kind of reaction does the equation represent?

A. alpha decay
B. beta decay
C. nuclear fission
D. nuclear fusion

41 Methane gas burns in the presence of oxygen to form water vapor and carbon dioxide. The balanced equation for this reaction is below.

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$$

Which of the following is the oxidation number of carbon in CO_2?

A. -2
B. 0
C. $+2$
D. $+4$

42 Which of the following statements describes properties of **most** metals?

A. They have high melting and boiling points.
B. They accept electrons to form negative ions.
C. They have densities lower than that of water.
D. They share electrons to form covalent bonds.

43 Which of the following statements explains how a buffer maintains pH when small amounts of a strong base are added?

A. The salt in the buffer absorbs the base.
B. The water in the buffer dilutes the base.
C. The weak acid of the buffer neutralizes the base.
D. The weak base of the buffer neutralizes the base.

Questions 44 and 45 are open-response questions.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF EACH QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 44 in the space provided in your Student Answer Booklet.

44 Carbon (C) reacts with bromine (Br) to form carbon tetrabromide (CBr_4).

a. Draw the Lewis dot structures for carbon (C) and bromine (Br).

b. Draw the Lewis dot structure for carbon tetrabromide (CBr_4).

c. Identify the shape of the CBr_4 molecule as predicted by valence-shell electron-pair repulsion (VSEPR) theory and explain why CBr_4 has this shape.

Write your answer to question 45 in the space provided in your Student Answer Booklet.

45 The chemical reactivity of an element can be predicted from its electron configuration.

a. Write the electron configurations for neon and for chlorine.

b. Using the electron configurations in part (a), compare the chemical reactivities of neon and chlorine. Explain your answer.

c. Identify an element that would have a chemical reactivity similar to that of chlorine. Explain your answer.

Massachusetts Comprehensive Assessment System
Chemistry Formula and Constants Sheet

Common Polyatomic Ions

Ion	Ionic Formula
Ammonium	NH_4^+
Carbonate	CO_3^{2-}
Hydroxide	OH^-
Nitrate	NO_3^-
Phosphate	PO_4^{3-}
Sulfate	SO_4^{2-}

Combined Gas Law: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Ideal Gas Law: $PV = nRT$

Molar Volume of Ideal Gas at STP: 22.4 L/mol

Ideal Gas Constant: $R = 0.0821\ L \cdot atm/mol \cdot K = 8.31\ L \cdot kPa/mol \cdot K$

STP: 1 atm (101.3 kPa), 273 K (0°C)

Absolute Temperature Conversion: $K = °C + 273$

Definition of pH: $pH = -\log[H_3O^+] = -\log[H^+]$

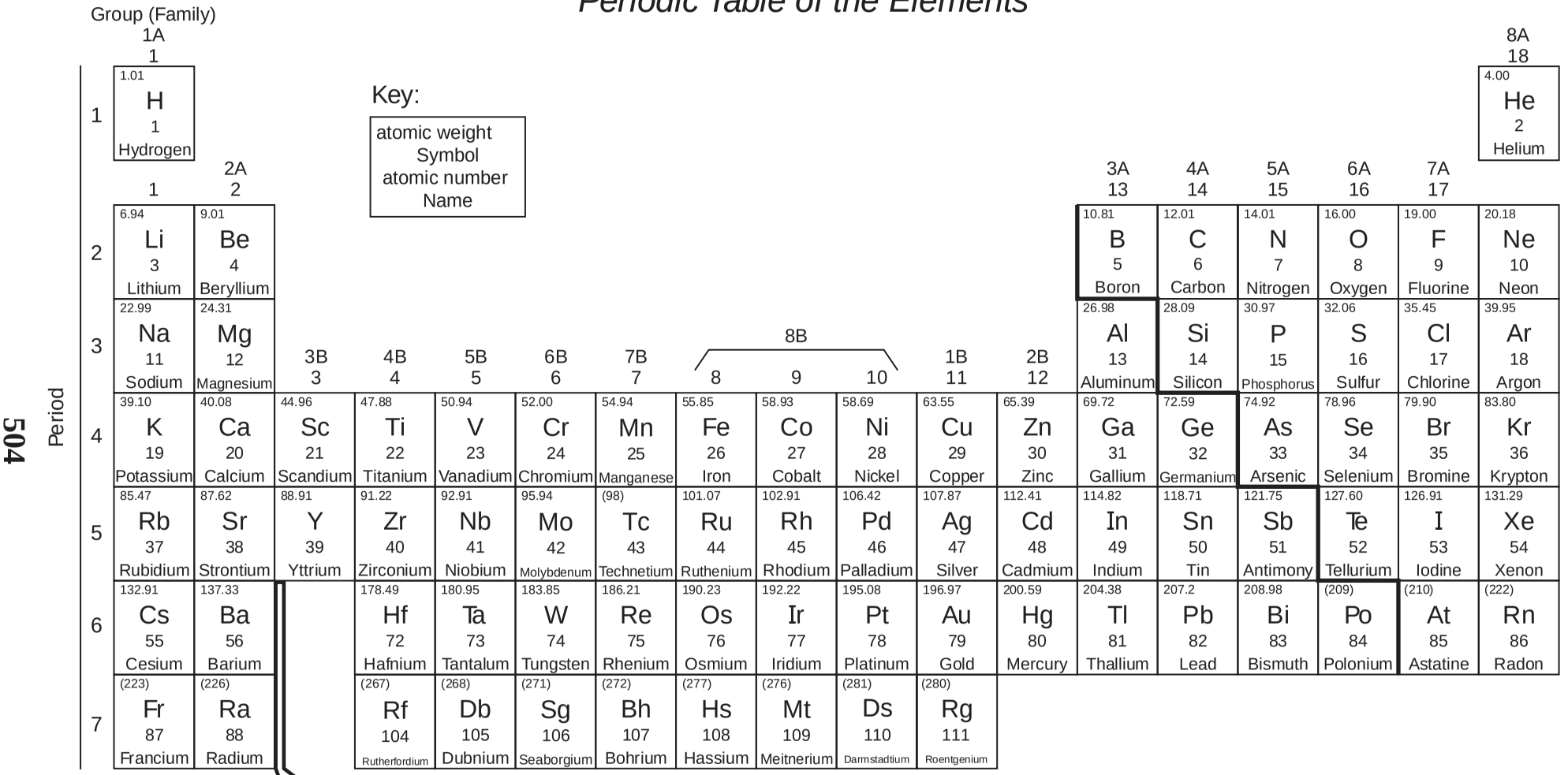
Avogadro's Number: 6.02×10^{23} particles/mol

Nuclear Symbols

Name	Symbol
Alpha particle	α or ${}_2^4He$
Beta particle	β or ${}_{-1}^0e$
Gamma ray	γ
Neutron	${}_0^1n$

Massachusetts Comprehensive Assessment System

Periodic Table of the Elements



*Revised based on IUPAC Commission on Atomic Weights and Isotopic Abundances, “Atomic Weights of the Elements 2007.”

High School Chemistry
Spring 2008 Released Items:
Reporting Categories, Standards, and Correct Answers*

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
1	483	*Properties of Matter and Thermochemistry*	1.2	D
2	483	*Atomic Structure and Periodicity*	2.1	B
3	484	*Properties of Matter and Thermochemistry*	6.2	C
4	484	*Solutions, Equilibrium, and Acid-Base Theory*	8.1	D
5	485	*Bonding and Reactions*	5.5	B
6	485	*Properties of Matter and Thermochemistry*	6.3	C
7	485	*Bonding and Reactions*	5.6	C
8	485	*Atomic Structure and Periodicity*	2.4	B
9	486	*Bonding and Reactions*	5.4	C
10	486	*Bonding and Reactions*	4.6	B
11	486	*Atomic Structure and Periodicity*	3.2	A
12	487	*Bonding and Reactions*	5.3	
13	488	*Atomic Structure and Periodicity*	2.3	D
14	488	*Bonding and Reactions*	4.5	C
15	488	*Properties of Matter and Thermochemistry*	6.4	B
16	489	*Solutions, Equilibrium, and Acid-Base Theory*	7.4	D
17	489	*Properties of Matter and Thermochemistry*	6.3	C
18	490	*Atomic Structure and Periodicity*	3.1	D
19	490	*Bonding and Reactions*	4.1	C
20	490	*Solutions, Equilibrium, and Acid-Base Theory*	8.2	A
21	491	*Bonding and Reactions*	4.3	B
22	491	*Solutions, Equilibrium, and Acid-Base Theory*	8.2	D
23	492	*Properties of Matter and Thermochemistry*	6.1	
24	493	*Bonding and Reactions*	4.1	A
25	493	*Solutions, Equilibrium, and Acid-Base Theory*	7.3	D
26	494	*Solutions, Equilibrium, and Acid-Base Theory*	8.3	B
27	494	*Atomic Structure and Periodicity*	2.3	C
28	495	*Bonding and Reactions*	4.2	D
29	495	*Atomic Structure and Periodicity*	2.2	C
30	495	*Solutions, Equilibrium, and Acid-Base Theory*	8.1	C
31	495	*Properties of Matter and Thermochemistry*	1.2	B
32	496	*Solutions, Equilibrium, and Acid-Base Theory*	7.5	
33	497	*Properties of Matter and Thermochemistry*	1.2	B
34	497	*Atomic Structure and Periodicity*	2.6	C
35	497	*Atomic Structure and Periodicity*	3.4	B
36	497	*Atomic Structure and Periodicity*	2.5	C
37	498	*Properties of Matter and Thermochemistry*	6.5	C
38	499	*Properties of Matter and Thermochemistry*	1.3	B
39	499	*Properties of Matter and Thermochemistry*	1.1	A
40	499	*Atomic Structure and Periodicity*	2.7	D
41	500	*Bonding and Reactions*	8.4	D
42	500	*Properties of Matter and Thermochemistry*	1.1	A

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
43	500	*Solutions, Equilibrium, and Acid-Base Theory*	8.3	C
44	501	*Bonding and Reactions*	4.4	
45	502	*Atomic Structure and Periodicity*	3.3	

***** Answers are provided here for multiple-choice items only. Sample responses and scoring guidelines for open-response items, which are indicated by shaded cells, will be posted to the Department's Web site later this year.