Cumulative Minitest

30 Questions **30 Minutes**

This cumulative minitest is designed to assess your mastery of the content in this volume. The questions have been designed to simulate actual MCAT questions in terms of format and degree of difficulty. They are based on the content categories associated with the Foundational Concepts that are the themes of this volume. They are also designed to test the scientific inquiry and reasoning skills that the test makers have identified as essential for success in medical school.

In this test, most of the questions are based on short passages that typically describe a laboratory experiment, a research study, or some similar process. There are also some questions that are not based on passages.

Use this test to measure your readiness for the actual MCAT. Try to answer all of the questions within the specified time limit. If you run out of time, you will know that you need to work on improving your pacing.

Complete answer explanations are provided at the end of the minitest. Pay particular attention to the answers for questions you got wrong or skipped. If necessary, go back and review the corresponding chapters or text sections.

Now turn the page and begin the Cumulative Minitest.

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Directions: *Choose the best answer to each of the following questions. Questions 1–5 are based on the following passage.*

Passage I

Blood pressure, or the force provided by the pumping heart to push the blood through the arteries of the circulatory system, plays an important role in the overall health of an individual and his/her propensity to cardiovascular disease. Blood pressure is typically measured in units of mm Hg. A normal value of systolic blood pressure for a healthy adult at rest is 120 mm Hg. In order to understand and research the influence of blood pressure and the resultant blood flow through a blood vessel, one often uses the mathematical relation known as Poiseuille's law.

Blood flow through a segment of blood vessel can be approximated by the flow of a fluid through a rigid pipe of constant radius using Poiseuille's law. Poiseuille's law describes the volumetric flow rate of a fluid, Q, as:

$$Q = \frac{\Delta P \cdot \pi \cdot R^4}{8 \cdot \eta \cdot L}$$

where ΔP = pressure gradient between two ends of the pipe; η = viscosity of the fluid; R = pipe radius; and L = pipe length.

The fluid's speed through the pipe, v, is related to the volumetric flow of the fluid by:

$$v = \frac{Q}{A}$$

where A is the cross-sectional area of the pipe. A fluid flowing through a pipe of constant radius has a greater speed at the center of the pipe than at the sides of the pipe.

1. Although it is commonly used to explain the dynamics of blood flow through a blood vessel, Poiseuille's law is an approximation. One possible reason that Poiseuille's law serves as an approximation is:
   A. tissue elasticity of the blood vessel.
   B. neutral pH of the blood.
   C. length of the blood vessel.
   D. variation in pressure gradient.
2. By what factor would the flow rate increase in a blood vessel whose radius was increased by 2?
   A. 4
   B. 8
   C. 16
   D. 32

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3. A blood vessel of radius 10 mm is partially obstructed to 1/2 of its original radius. If the average blood speed is initially 100 cm/s, what is the average blood speed in the obstructed area?
   A. 50 cm/s
   B. 100 cm/s
   C. 200 cm/s
   D. 400 cm/s
4. The kinetic energy per unit volume of blood passing through a segment of blood vessel at a speed of 0.50 m/s is: (Note: the density of blood, $\rho_b = 1.0 \times 10^3$ kg/m^3)
   A. 100 J/m^3
   B. 115 J/m^3
   C. 120 J/m^3
   D. 125 J/m^3
5. A blood vessel segment with a pressure of 130 mm Hg at one end of the vessel (Point A) and a pressure of 100 mm Hg at the other end (Point B) yields a volumetric blood flow rate of 5000 mL/min. If the pressure at Point A is now elevated to 150 mm Hg and the pressure at Point B elevated to 120 mm Hg, the resultant volumetric blood flow will be:
   A. 5000 ml/min
   B. 10,000 ml/min
   C. 20,000 ml/min
   D. 40,000 ml/min

Questions 6 through 8 are not based on a passage.

6. A solution is prepared with 25 g of NaCl in 500 mL of water. The molarity of the solution is:
   A. 0.37 M
   B. 0.52 M
   C. 0.86 M
   D. 0.98 M
7. The pH of a solution with $[H^+] = 7.5 \times 10^{-5} \frac{moles}{L}$ is most closely:
   A. 2
   B. 4
   C. 6
   D. 8
8. Given the chemical equation $Zn + HCl \rightarrow ZnCl_2 + H_2$, the balanced equation is:
   A. $2Zn + 2HCl \rightarrow ZnCl_2 + H_2$
   B. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
   C. $2Zn + HCl \rightarrow 2ZnCl_2 + H_2$
   D. $Zn + 2HCl \rightarrow ZnCl_2 + 2H_2$

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Questions 9–13 are based on the following passage.

Passage II

An important characteristic of the thermal properties of matter is the specific heat capacity. The specific heat capacity, designated by the symbol c, represents the amount of thermal energy (in joules) required to raise the temperature of 1 kg of the substance by 1 °C. The specific heat capacity, c, of an object is related to the thermal energy, Q, by the equation: $Q = mc\Delta T$, where m is the mass of the object (in kilograms) and ΔT is the change in temperature (in degrees Celsius).

An experimental procedure used to determine the specific heat capacity of an object is known as calorimetry. In a typical calorimetry experiment, one places the object of known mass and initial temperature into a container (also referred to as a calorimeter) usually filled with water of known mass, specific heat capacity, and initial temperature. In these types of experiments, the object is usually at a much higher temperature than the water. As the object is placed in the water, the object at the higher temperature loses heat while the water at the lower temperature gains heat. The transfer of heat continues until the system (object and water) reaches the same temperature (thermal equilibrium). Based on the relationship between the transfer of thermal energy in a calorimeter, it is possible to determine the specific heat capacity of an unknown sample, assuming that all other information is known or can be easily obtained.

9. The units of specific heat capacity are:
   A. $\dfrac{J}{kg \cdot {}^\circ C}$
   B. $\dfrac{kg \cdot {}^\circ C}{J}$
   C. $\dfrac{J \cdot {}^\circ C}{kg}$
   D. $\dfrac{J \cdot {}^\circ C}{kg}$
10. In one experiment, a scientist noted that the measured heat of the object in water taken after some time was less than the expected theoretical calculation. A possible reason for the discrepancy was that the theoretical calculation probably did not take into account:
    A. initial temperature of water
    B. loss of heat to the environment
    C. size of the object
    D. amount of water
11. Assuming the calorimeter is a closed system, the correct expression for the exchange of thermal energy in a calorimeter experiment is:
    A. Heat gained by object + Heat gained by container = Heat lost by water
    B. Heat gained by object = Heat lost by water + Heat lost by container
    C. Heat lost by object + Heat lost by container = Heat gained by water
    D. Heat lost by object = Heat gained by water + Heat gained by container

12. The calorimetry experiment and the calculations used to determine the specific heat capacity of the unknown object is based upon:
    A. Zeroth Law of Thermodynamics
    B. First Law of Thermodynamics
    C. Second law of Thermodynamics
    D. Third Law of Thermodynamics
13. Hot coffee at a temperature of 73 °C is poured into a cup of volume 250 mL. Over a certain time, the coffee has cooled to room temperature (22 °C). If the thermal energy released to the environment is 50 kJ, the specific heat capacity of the coffee is: (NOTE: Assume the density of coffee is equal to the density of water ($\rho = 1\ \frac{\text{g}}{\text{mL}}$).)
    A. $2.4\ \frac{g \cdot {}^\circ\text{C}}{J}$
    B. $2.4\ \frac{J}{g \cdot {}^\circ\text{C}}$
    C. $4.1\ \frac{g \cdot {}^\circ\text{C}}{J}$
    D. $4.1\ \frac{J}{g \cdot {}^\circ\text{C}}$

Questions 14–16 are not based on a passage.

14. A 5-kg stone dropped from a height of 25.0 m reaches a velocity of 22 m/s as it strikes the ground. The final speed of a 10-kg stone dropped from 25.0 m will be:
    A. 10 m/s
    B. 17 m/s
    C. 22 m/s
    D. 44 m/s
15. The electric force that exists between two charged particles $q_1 = +2.0\ \mu$C and $q_2 = +3.0\ \mu$C is 250 N. The distance of separation between the two charged particles is:
    A. 1.5 cm
    B. 4.6 cm
    C. 7.8 cm
    D. 15.0 cm
16. The force exerted on a 500-g object causing it to accelerate 6 m/s^2 is:
    A. 3 N
    B. 30 N
    C. 300 N
    D. 3000 N

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Questions 17–21 are based on the following passage.

Passage III

The space shuttle's reusable solid rocket boosters provide most of the liftoff thrust to propel the rocket into orbit at about 45.7 km above Earth's surface.

The propellant for each of the two solid rocket boosters weighs 5×10^5 kg. The propellant consists of a mixture of powdered aluminum and solid ammonium perchlorate which react upon ignition as follows:

$$10Al\ (s) + 6NH_4ClO_4\ (s) \rightarrow 4Al_2O_3\ (s) + 2AlCl_3\ (s) + 3N_2\ (g) + 12H_2O\ (g)$$
$$\Delta G_{rxn} = -8421\ \text{kJ}$$

The aluminum powder is 16% by weight of the propellant, and the ammonium perchlorate is 69.8% by weight. Also added is a catalyst, a binding agent, and an epoxy curing agent which makes the consistency of the propellant much like a rubber eraser.

Ammonium perchlorate decomposes at 240 °C to chlorine, oxygen, nitrogen, and water vapor. It is the oxygen reacting with the aluminum that provides the huge amounts of thrust needed for the orbiter to escape the gravitational pull of the earth. For every gram of aluminum that reacts, 33 kJ of thermal energy is released. The reaction heats the inside of the solid rocket boosters to 5800 °C causing the gaseous products to expand rapidly. It is the expanding gases that lift the rocket booster. All of the fuel is burned in about two minutes.

Aluminum has a ΔH°_{vap} of 294 kJ/mole, and its boiling point is 2792 K.

17. Why is the aluminum used in the solid rocket boosters in powder form?
    - **A.** Powder can be distributed evenly throughout the propellant.
    - **B.** Powder will react faster.
    - **C.** Powder provides more surface area for the reaction to take place.
    - **D.** All of the above
18. The value of ΔS°_{vap} of aluminum is:
    - **A.** 9.5 kJ/mole K
    - **B.** 87 J/mole K
    - **C.** 12 J/mole K
    - **D.** 105 J/mole K
19. What is the approximate total number of moles of aluminum in the solid rocket boosters?
    - **A.** 18 million moles
    - **B.** 6 million moles
    - **C.** 3 million moles
    - **D.** 18 thousand moles

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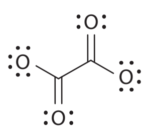
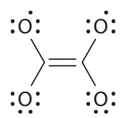
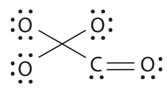
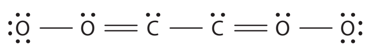
20. What is the approximate percentage of oxygen, by weight, in the solid propellant contributed by the ammonium perchlorate?
    A. 38%
    B. 70%
    C. 47%
    D. 14%
21. What is the average velocity of the space shuttle as it approaches its orbit?
    A. 23 km/min
    B. 858 mi/hr
    C. 382 m/sec
    D. all of the above

Questions 22–25 are not based on a passage.

22. What is the electron configuration of the ion of cobalt that is present in CoC_2O_4?
    A. $1s^22s^22^63s^23p^64s^23d^7$
    B. $1s^22s^22^63s^23p^63d^7$
    C. $1s^22s^22^63s^23p^63d^74s^2$
    D. $1s^22s^22^63s^23p^54s^23d^5$
23. Which of the following is a proper Lewis structure for the oxalate ion $C_2O_4^{-2}$?
    A. 
    B. 
    C. 
    D. 
24. From the top of a 35-m building, two objects identical in size, shape, and mass are released at the same time with one dropped from rest and the other thrown downward with a speed of 15 m/s. After the first second, you can state that:
    A. Both objects will accelerate at the same rate, equal to $-9.8\ m/s^2$.
    B. Both objects will accelerate at the same rate, equal to $-15\ m/s^2$.
    C. The thrown object will accelerate faster than the object released from rest.
    D. Both objects will not accelerate.

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25. The volume of 4.0 M H_2SO_4 required to prepare 600 mL of 0.5 M H_2SO_4 is:
   A. 30 mL
   B. 45 mL
   C. 60 mL
   D. 75 mL

Questions 26–30 are based on the following passage.

Passage IV

Continual exposure to indoor air pollutants in homes or other residential structures poses significant environmental and health concerns. One such pollutant is radon, a radioactive gas found in the soils and rocks of the earth's crust that permeates into homes through gaps in the floor, cracks in walls, or through the water supply. Radon is invisible and odorless, and becomes a concern when elevated concentrations of the gas are allowed to build up inside the home.

The isotope of radon commonly found in homes is Radon-222, a product of the uranium-238 decay chain, formed by the decay of Radium-226 through the emission of an alpha particle. An alpha particle is a type of ionizing radiation involved in the decay process of some unstable atoms. An alpha particle is a helium nucleus with two protons and two neutrons. Alpha particles, however, are heavy in comparison to other particles emitted during decay processes such as electrons and thus only travel on the order of several centimeters before they have depleted their energy.

Radon-222, in turn, decays spontaneously into Polonium-218 by emitting an alpha particle according to:

$$\begin{array}{lc} \text{Radium-226} \rightarrow & \text{Radon-222} + \alpha \\ & \downarrow \\ & \text{Polonium-218} + \alpha \end{array}$$

Radium-226 has a half-life of 1,600 years and Radon-222 has a half-life of 3.8 days.

26. Assuming an initial concentration of radon gas inside a house, what fraction of the initial concentration will remain in the house after four half-lives?
   A. 0.940
   B. 0.500
   C. 0.125
   D. 0.060

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27. In general, isotopes have:
    A. same atomic number, different mass number, same chemical properties, and different physical properties
    B. different atomic number, same mass number, same chemical properties, and different physical properties
    C. same atomic number, different mass number, different chemical properties, and same physical properties
    D. different atomic number, same mass number, different chemical properties, and same physical properties
28. The atomic composition of $^{222}_{86}Rn$ is:
    A. 222 protons, 136 neutrons, and 86 electrons
    B. 222 protons, 136 neutrons, and 222 electrons
    C. 86 protons, 222 neutrons, and 86 electrons
    D. 86 protons, 136 neutrons, and 86 electrons
29. Given that 86 is the atomic number of Rn-222, then the number of neutrons of Po-218 is:
    A. 148
    B. 134
    C. 124
    D. 120
30. Rn-222 spontaneously decays to Po-218 by the emission of an alpha particle. The correct balanced expression of this reaction is given by the following:
    A. $^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$
    B. $^{222}_{86}Rn \rightarrow {}^{218}_{85}Po + {}^{2}_{1}He$
    C. $^{222}_{86}Rn \rightarrow {}^{218}_{85}Po + {}^{4}_{2}He$
    D. $^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{2}_{1}He$

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Cumulative Minitest Answers and Explanations

1. **The correct answer is A.** A description of Poiseuille's law stated that it was a relation used to determine the volumetric flow rate of a fluid through a rigid pipe of constant radius. No variable in Poiseuille's law implies a need or knowledge of the pH of the fluid so that is not an issue and choice B is not correct. Blood vessel length and pressure gradient are variables addressed in the equation and found in measurements of a blood vessel. It is the vessel elasticity that is present in normal vessels that is not described by Poiseuille's law. In fact, the inclusion of elasticity effects into a mathematical equation of blood flow through a vessel results in a significantly complicated calculation. Thus the correct answer is choice A.
2. **The correct answer is C.** From Poiseuille's law, flow rate is proportional to $(Radius)^4$. This means that if the radius of the blood vessel is increased by 2 or doubled, then the flow rate increases by $(2 \cdot Radius)^4 = 16 \cdot (Radius)^4$.
3. **The correct answer is D.** From the passage, the average blood speed is given by: $v = \frac{Q}{A}$, where A is the cross-sectional area of the pipe. Since the flow rate is constant,

   $$Q_{\text{orig}} = Q_{\text{obs}}$$

   Or:

   $$v_{\text{orig}} \cdot A_{\text{orig}} = v_{\text{obs}} \cdot A_{\text{obs}}$$

   In the question, $v_{\text{orig}} = 100$ cm/s, $A_{\text{orig}} = \pi(10\text{ mm})^2$, and $A_{\text{obs}} = \pi(5\text{ mm})^2$. Thus,

   $$v_{\text{obs}} = v_{\text{orig}} \cdot \left(\frac{A_{\text{orig}}}{A_{\text{obs}}}\right) = \left(100\,\frac{\text{cm}}{\text{s}}\right) \cdot \left(\frac{\pi(10\text{ mm})^2}{\pi(5\text{ mm})^2}\right) = \left(100\,\frac{\text{cm}}{\text{s}}\right) \cdot (4) = 400\,\frac{\text{cm}}{\text{s}}$$

4. **The correct answer is D.** The kinetic energy per unit volume of blood is defined by the equation:

   $$KE = \frac{1}{2}mv^2 = \frac{1}{2}(\rho \cdot \text{V})v^2$$

   where ρ is the density of blood and V is its volume. Substituting given values into the equation yields:

   $$KE = \frac{1}{2}\left(1000\,\frac{\text{kg}}{\text{m}^3} \cdot \text{V}\right) \cdot \left(0.5\,\frac{\text{m}}{\text{s}}\right)^2 = 500 \cdot 0.25\,\frac{\text{J}}{\text{m}^3} = 125\,\frac{\text{J}}{\text{m}^3}$$

5. **The correct answer is A.** The flow rate, as described by Poiseuille's law, is directly proportional to the change in pressure and not any one specific pressure value. Although the individual pressure values in the second case are both elevated, the difference in the pressure values still remains the same, i.e., 30 mm Hg. Thus the resultant volumetric blood flow will not have changed and is 5000 mL/min and the correct answer is choice A.

6. **The correct answer is C.** First you must calculate the number of moles of NaCl:

$$\text{Number of moles of NaCl} = \frac{\text{Amount of NaCl present in grams}}{\text{Molecular weight of NaCl}}$$
$$= \frac{25\text{ g}}{58.4\frac{\text{g}}{\text{mole}}} = 0.43\text{ moles}$$

Molarity is defined as the number of moles in 1 liter of solution. There are 0.43 moles in 0.5 L (or 1/2 of a liter) of solution and thus molarity, $M = 2 \times 0.43\ \frac{\text{moles}}{\text{L}} = 0.86\,\text{M}$.

7. **The correct answer is B.** The pH of a solution is defined as:

$$\text{pH} = -\log[7.5 \times 10^{-5}] = -\log[7.5] - \log[10^{-5}]$$
$$= -0.875 - (-5) = -0.875 + 5 = 4.13$$

8. **The correct answer is B.** A chemical equation is balanced when the number of atoms on the left side of the equation is equal to the number of atoms on the right side of the equation.

	LEFT SIDE			RIGHT SIDE		
CHEMICAL EQUATION	Zn	H	Cl	Zn	H	Cl
$2Zn + 2HCl \rightarrow ZnCl_2 + H_2$	2	2	2	1	2	2
$Zn + 2HCl \rightarrow ZnCl_2 + H_2$	1	2	2	1	2	2
$2Zn + HCl \rightarrow 2ZnCl_2 + H_2$	2	1	1	2	2	4
$Zn + 2HCl \rightarrow ZnCl_2 + 2H_2$	1	2	2	1	4	2

The only equation in which both sides are equal in terms of the number of atoms is $Zn + 2HCl \rightarrow ZnCl_2 + H_2$.

9. **The correct answer is A.** Rearranging the equation for thermal energy given in the passage to solve for the specific heat capacity:

$$Q = mc\Delta T \Rightarrow c = \frac{Q}{m\Delta T}$$

Substituting the units for each of the variables represented in the equation for c yields:

$$c = \frac{Q}{m\Delta T}\left[\frac{J}{\text{kg}\cdot{}^\circ\text{C}}\right]$$

10. **The correct answer is B.** A calorimetry experiment is based upon the principle of the conservation of energy, i.e., the heat lost by the object is equal to the heat gained by the water and the container. It is possible that if the calorimeter is not a closed system, heat could also be lost to the environment. Any loss of heat encountered experimentally must be accounted for theoretically if the specific heat of the object to be calculated is to be correct. Thus, the correct answer is choice B.

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11. **The correct answer is D.** Thermal energy travels from hot to cold. Thus, the heat exhibited by the unknown object will lose its heat once placed into the calorimeter. The heat lost by the object will be transferred to the water and the container. This is summarized by the conservation of energy. The correct answer is choice D.

12. **The correct answer is B.** This question can be answered by summarizing the definitions for all four Laws of Thermodynamics:

    Zeroth Law of Thermodynamics If two objects A and B are in thermal equilibrium, and objects B and C are also in thermal equilibrium, then objects A and C are also in thermal equilibrium.

    First Law of Thermodynamics This law, a generalized expression of the law of conservation of energy, states that the thermal energy (heat) added to a closed system (ΔQ) is equal to the increased internal energy of the system (ΔU) plus the amount of energy in the form of work done by the system (ΔW) or $\Delta Q = \Delta U + \Delta W$.

    Second Law of Thermodynamics A system subjected to a spontaneous change will respond such that its disorder or entropy will increase or at least will remain the same.

    Third Law of Thermodynamics As the temperature of a system approaches absolute zero, its entropy approaches a minimum value.

    The correct response is choice B.

13. **The correct answer is D.** This problem can be solved by first writing down the equation for thermal energy and then algebraically solving for the specific heat capacity:

$$Q = mc\Delta T \Rightarrow c = \frac{Q}{m\Delta T}$$

The heat released to the environment is 50 kJ but because it is removed from the coffee as opposed to being added to the system, the value for Q is negative and thus $Q = -50$ kJ. The change in temperature is $\Delta T = T_f - T_i = 22\,^\circ\text{C} - 71\,^\circ\text{C} = -49\,^\circ\text{C}$. The final unknown is the mass of the coffee which is not given in the problem but the volume of coffee can be calculated with the knowledge of the density of the coffee which is equivalent to the density of water. The mass of the coffee can be found from:

$$\rho = \frac{m}{V} \Rightarrow m = \rho V = \left(1\frac{\text{g}}{\text{mL}}\right)(250\text{ mL}) = 250\text{ g}$$

Substituting into the expression for the specific heat capacity yields:

$$c = \frac{Q}{m\Delta T} = \frac{-50{,}000\,J}{(250\,g)(-49\,^\circ\text{C})} = 4.08\frac{J}{g\cdot\,^\circ\text{C}}$$

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14. **The correct answer is C.** The question involves the effect of mass on the final velocity of an object dropped from rest. The equation used to determine the final velocity of an object dropped from rest is:

$$v_f^2 = v_i^2 + 2a\Delta y$$

where $a = -\mathrm{g}$ and $\Delta y = -$height (as measured from the top and moving downward). As one can see, mass is not a factor in the equation and thus doubling the mass will not have an effect on the final velocity of the object as it strikes the ground.

15. **The correct answer is A.** The equation that relates the electric force ($\boldsymbol{F}$), the electric charge of two charged particles (q_1, q_2) and the distance of separation between the charged particles (r) is given by Coulomb's law:

$$\boldsymbol{F} = k\frac{q_1 q_2}{r^2}$$

Rearranging the equation for the distance of separation yields:

$$r = \sqrt{\frac{kq_1 q_2}{F}}$$

Substituting into the expression for r gives:

$$r = \sqrt{\frac{\left(9 \times 10^9 \dfrac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right)(+2.0 \times 10^{-6}\ \mathrm{C})(+3.0 \times 10^{-6}\ \mathrm{C})}{(250\ \mathrm{N})}}$$

$$= 1.469 \times 10^{-2}\ \mathrm{m} = 1.47\ \mathrm{cm}$$

16. **The correct answer is A.** Force can be determined using Newton's Second Law: $\mathbf{F} = \mathrm{m}\mathbf{a}$. In this case, m = mass = 500 g and $\mathbf{a}$ = acceleration = 6 m/s^2. However, before one can substitute these values into the equation, the mass must be expressed in units of kilograms, not grams. Thus, the mass value given above must be divided by 1000, meaning the decimal place is moved to the left by three places. Therefore, m = 0.500 kg, $\mathbf{a}$ = 6 m/s^2 and

$$\mathbf{F} = (0.500\ \mathrm{kg})(6\ \mathrm{m/s^2}) = 3.0\ \mathrm{N}$$

17. **The correct answer is D.** The kinetic molecular theory states in part that for reactions to occur reactants must come in contact with each other. The speed of a reaction depends on several factors including the concentration of the reactants, and the probability of reactants coming together. A powder can be more evenly distributed than chunks of aluminum which makes the concentration even throughout the booster. In other words there will not be any volumes with low or zero concentration of aluminum. This means that choice A leads to a faster reaction. The greater the surface area of the reactants, the more potential places where the reactants can meet and lead to a successful reaction. This means that choice C leads to a faster reaction. Choice B simply restates that choices A and C lead to a faster reaction. Because choices A, B, and C are all true, choice D (all of the above) is the best answer.

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18. **The correct answer is D.** Vaporization at the boiling point is defined as an equilibrium process. For an equilibrium process, ΔG is defined to be zero, meaning there is neither a tendency for the reaction to shift to the right (products) nor to the left (reactants). From the definition of free energy,

$$\Delta G = \Delta H - T\Delta S$$

Because $\Delta G = 0$ at the boiling point, the above equation rearranges to:

$$\frac{\Delta H_{vap}}{T} = \Delta S_{vap} \quad \text{or} \quad \frac{294\,\text{kJ/mol}}{2792\,\text{K}} = 0.105\,\text{kJ/molK} \quad \text{or} \quad 105\,\text{J/mol K}$$

19. **The correct answer is B.** This problem is worked in the following steps:

$$\begin{array}{ccccccccc} \textit{mass} & 1 & \textit{mass} & 2 & \textit{mass} & 3 & \textit{mass} & 4 & \textit{mol} \\ \textit{one booster} & \rightarrow & \textit{two boosters} & \rightarrow & \text{Al(kg)} & \rightarrow & \text{Al}(g) & \rightarrow & \text{Al} \end{array}$$

(1) There are two rocket boosters each with a mass of 5×10^5 kg of propellant, so the total mass is 1×10^6 kg.

(2) The propellant is not all aluminum, so you must use the percentage Al to determine how much of the propellant is aluminum. A percentage of 16% means that 16 out of every 100 parts of the total are aluminum.

$$1 \times 10^6\,\text{kg propellant} \times \frac{16\,\text{kg Al}}{100\,\text{kg propellant}} = 1.6 \times 10^5\,\text{kg Al}$$

(3) Molar mass are usually given in g/mol so we need to convert kg Al to g Al

$$1.6 \times 10^5\,\text{kg Al} \times \frac{1000\,\text{g Al}}{1\,\text{kg al}} = 1.6 \times 10^8\,\text{g Al}$$

(4) Finally, the g of Al are converted to moles using the atomic mass of aluminum.

$$1.6 \times 10^8\,\text{g Al} \times \frac{1\,\text{mol Al}}{27\,\text{g Al}} = 5.9 \times 10^6\,\text{mol Al}$$

This answer is closest to 6 million moles. Note that if you do not include both boosters (step 1 omitted), you will get incorrect answer choice C. You will get incorrect answer choice A if only one booster is used and the total mass is used (steps 1 and 2 omitted). You will get incorrect answer choice D if steps 1, 2, and 3 are omitted.

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20. **The correct answer is A.** This problem is worked in the following steps.

$$\underset{propellant}{100\text{ g}} \xrightarrow{1} \underset{NH_4ClO_4}{mass} \xrightarrow{2} \underset{O}{mass} \xrightarrow{3} \underset{O}{\%}$$

(1) Because you have a percentage, it is convenient to pick a 100 g sample of the propellant to start your calculation. You could pick any size, but 100 g makes the calculation simpler. The propellant is 69.8% ammonium perchlorate, so there are 69.8 g of ammonium perchlorate in 100 g of propellant.

(2) To get the mass of oxygen, you must determine how much oxygen is in a sample of ammonium perchlorate. The molar mass of ammonium perchlorate is the sum of the atomic masses of the atoms in one mole: $(14.01) + (4 \times 1.008) + (35.45) + (4 \times 16.00)\text{g} = 117.49$ g/mol NH_4ClO_4. In one mole of ammonium perchlorate, there are 64.00 g of oxygen.

$$69.8\text{ g NH}_4\text{ClO}_4 \times \frac{64\text{ g O}}{117.49\text{ g NH}_4\text{ClO}_4} = 38.02\text{ g O}$$

(3) Finally, because 100 g of propellant was used to start the calculation, the percentage of oxygen is $(38.02\text{ g O}/100.0\text{ g total}) \times 100\% = 38\%$ O.

21. **The correct answer is D.** The average velocity over a time interval is:

$$v_{ave} = \frac{\Delta d}{\Delta t} = \frac{d_f - d_i}{t_f - t_i}.$$

where d = distance, t = time, Δ indicates change, and the subscript f indicates final and the subscript i indicates initial. If you take the surface of Earth as $d_i = 0$ and the time the rocket boosters are lit as $t_i = 0$, then $d_f = 45.7$ km and $t_f = 2.0$ min. This leads to an average velocity of 45.7 km/2.0 min = 22.9 km/min (choice A). You must check if choices B and C are numerically equal to choice A.

For choice B,

$$22.9\,\frac{\text{km}}{\text{min}} \times \frac{1\text{ mi}}{1.609\text{ km}} \times \frac{60\text{ min}}{1\text{ hr}} = 858\,\frac{\text{mi}}{\text{hr}}$$

For choice C,

$$22.9\,\frac{\text{km}}{\text{min}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ min}}{60\text{ sec}} = 382\,\frac{\text{m}}{\text{sec}}$$

Choices A, B, and C are equal, so the correct answer is “all of the above.”

22. **The correct answer is B.** To work this problem you must recognize the common polyatomic ion oxalate, $C_2O_4^{2-}$. Because the compound CoC_2O_4 is neutral, the charge on the Co must balance the charge on the oxalate. For this to be true, cobalt must be a 2+ ion. Neutral cobalt atoms have 27 electrons and have electron configuration $1s^22s^22p^63s^23p^64s^23d^7$ (Answer choices A and C). It may seem that choice D is the correct answer because it removes the last two electrons that entered the atom. In the ions of transition metals the 4s electrons are lost before the 3d even though the 3d are the last to go into the atom. This means all transition metal cations have the electron configuration $[NG]nd^x$, where [NG] is the noble gas core electron configuration, nd is the appropriate 3, 4, 5, or 6d level, and x is the number of electrons needed to give the correct charge. Because Co must lose 2 electrons to obtain a 2+ charge, it loses its two 4s electrons leaving seven 3d electrons and the electron configuration: $1s^22s^22p^63s^23p^63d^7$ which is answer choice B.
23. **The correct answer is A.** The total number of valence electrons for oxalate is ($2 \times$ # valence e^- per C) + ($4 \times$ # of valence e^- per O) + (2 extra electrons for the 2- charge) $= (2 \times 4) + (4 \times 6) + (2) = 34$ electrons. Structure B is incorrect because the upper two oxygen atoms do not have an octet of electrons. Structure C has 36 or 2 too many electrons, so it is incorrect. Structure D is incorrect because while it has the correct number of electrons, it places a formal change on all atoms including an unlikely positive charge on oxygen. Structure A has 34 electrons and has only two formal charges and the formal charges reside on the electronegative oxygen atoms.
24. **The correct answer is A.** In free-fall motion along the y-axis, whether the object is dropped or thrown, once it leaves the hand of the thrower, the only force acting on the object is gravity, meaning that both objects accelerate at $9.8\ m/s^2$. The only difference between the two objects is their initial velocity which is 0 m/s for the dropped object and -15 m/s for the thrown object.
25. **The correct answer is D.** This problem can be solved using the relationship:

$$M_1V_1 = M_2V_2$$

where: M_1 is the molarity of the original solution ($M_1 = 0.5\ M$)
V_1 is the volume of the original solution ($V_1 = 0.6$ L)
M_2 is the molarity of the new solution ($M_2 = 4.0\ M$)
V_2 is the volume of the new solution ($V_2 =$ unknown)

$$V_2 = \frac{M_1V_1}{M_2} = \frac{(0.5\ M)(0.6\ \text{L})}{(4\ M)} = 0.075\ \text{L} = 75\ \text{mL}$$

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26. **The correct answer is D.** The half-life of a radioactive substance is the time it takes for the number of radioactive nuclei to decrease by one-half. So if [Rn] represents an initial quantity of Rn-222, then:

$$[Rn] \xrightarrow{\text{1 half-life}} \frac{1}{2}[Rn] \xrightarrow{\text{1 half-life}} \frac{1}{4}[Rn] \xrightarrow{\text{1 half-life}} \frac{1}{8}[Rn] \xrightarrow{\text{1 half-life}} \frac{1}{16}[Rn]$$

So, after four half-lives, the number of radioactive nuclei in an original sample of Rn-222 is reduced by $\frac{1}{16}$ or 0.06.

27. **The correct answer is A.** This question can be answered by general knowledge of the chemical composition of elemental substances and isotopes. Isotopes are nuclei with different number of neutrons and the same number of protons. Because the number of protons is described by an element's atomic number (Z), isotopes have the same atomic number but a different mass number that is defined as the total number of nucleons (protons and neutrons). Chemical properties of an element are based on the number and arrangement of electrons while physical properties arise from the nucleus. Because isotopes have the same number of electrons, as indicated by the atomic number (Z), isotopes have the same chemical properties. In addition, isotopes have a different number of neutrons, as indicated by the mass number (A) and thus have different physical properties.

28. **The correct answer is D.** In general, the atomic composition of an element, X, is given by ${}^{A}_{Z}X$ where:

$$A = \text{mass number} = \text{number of nucleons} = \text{number of protons and neutrons}$$
$$Z = \text{atomic number} = \text{number of protons} = \text{number of electrons}$$
$$N = A - Z = \text{number of neutrons}$$

Thus, ${}^{222}_{86}Rn$ has 86 protons, $222 - 86 = 136$ neutrons, and 86 electrons.

29. **The correct answer is B.** Radon-222 decays spontaneously into Polonium-218 by emitting an alpha particle which means that the atomic number of Polonium-218 is 84. The number of neutrons in Polonium-218 can be determined by $N = A - Z = 218 - 84 = 134$.

30. **The correct answer is A.** The atomic number of Rn-222 is 86 and the atomic number of Po-218 is 84. An alpha particle is a helium nucleus which has two protons and two neutrons. Thus, for an alpha particle, $A = 4$, $Z = 2$ and ${}^{4}_{2}\alpha$. In order for a reaction to be correct, it must be balanced as far as each side having the same quantities of A and Z. The correct reaction described in the problem is: ${}^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$.

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