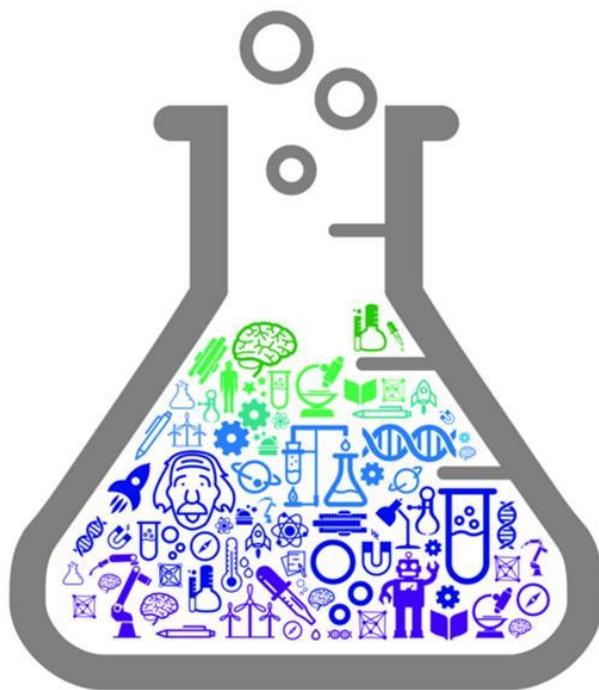


12TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2015



December 2(Wed)-11(Fri), 2015 | Daegu, Republic of Korea

Multiple Choice Competition

– Solution –

December 4, 2015



SOLUTION

[CHEMISTRY]

1.

(Answer) D

(Explanation) Atom is formed of proton(s), electron(s) and neutron(s), where the atomic number is defined by the number of protons, and the mass number is defined by the number sum of protons and neutrons. Any neutral atom has equal numbers of protons and electrons. When two atoms have the same number of protons but different numbers of neutrons, they are classified as same elements in the isotopic relation.

II has 8 neutrons, and $a = 8$. (A is incorrect)

II has 7 electrons, and $b = 7$. (B is incorrect)

Atomic number of I is 7. (C is incorrect)

I and II have same number of protons but different numbers of neutrons; they are isotopes of the same element (D is correct).

2.

(Answer) C

(Explanation) All the four ions, in the question, are isoelectronic but have different nuclear charges. Since the numbers of electrons are the same, the higher the nuclear charge is, the smaller the ionic radius is.

Ionic radii sizes: $O^{2-} > F^- > Na^+ > Mg^{2+}$

3.

(Answer) D

(Explanation) Because the molecular geometry of H_2Se is bent linear, with two lone-pair electrons on the central atom, Se, there is a non-zero dipole moment in H_2Se . The other three have symmetric molecular geometry and have zero dipole moment.

4.

(Answer) B

(Explanation) When the concentration of the reactant is linearly decreasing with time, the reaction is zeroth order reaction, that is, $n = 0$.

Reaction rate = k

By writing the equation in the unit,

$M/s =$ (the unit for the k)

The unit for the k is M/s .



SOLUTION

5.

(Answer) C

(Explanation) According to the density information (1.25 g/L), 1 mole of **X**, corresponding to a volume of 22.4 L, has a mass of 28 g. That is, the molecular mass of **X** is 28 g/mol.

Hydrocarbon **X** consists of only hydrogen (H, atomic mass: 1 g/mol) and carbon (C, atomic mass: 12 g/mol), and will have a chemical formula of C_mH_n . Considering the molecular mass of **X**, it is deduced that $m = 2$, and $n = 4$.

As an **X** molecule (28 g/mol) consists of two carbon atoms (24 g/mol) and four hydrogen atoms (4 g/mol), the mass fraction of carbon in **X** is $24/28 = 85.7\%$.

6.

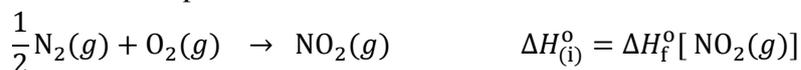
(Answer) B

(Explanation) The electron configuration of the ground state of ${}_{13}\text{Al}$ is $1s^22s^22p^63p^3$ and the most stable ion of Al is Al^{3+} . Therefore, the electron configuration of Al^{3+} is $1s^22s^22p^6$.

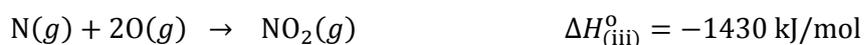
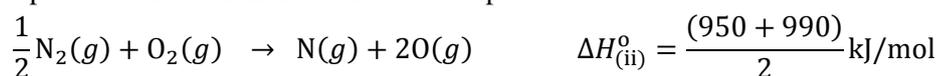
7.

(Answer) C

(Explanation) ΔH_f° of $\text{NO}_2(g)$ is the enthalpy change for a process where $\text{NO}_2(g)$ is formed from the most stable elemental components:



The above process can be broken down to two steps



($\Delta H_{(ii)}^\circ$ and $\Delta H_{(iii)}^\circ$ can be evaluated from the diagram given in question)

As the enthalpy is an extensive property, $\Delta H_{(i)}^\circ = \Delta H_{(ii)}^\circ + \Delta H_{(iii)}^\circ$, and consequently, ΔH_f° of $\text{NO}_2(g)$ is -460 kJ/mol .



8.

(Answer) B

(Explanation)

In aqua, HCN is dissociated to H^+ and CN^- , where the final concentrations of $[\text{HCN}]$, $[\text{H}^+]$ and $[\text{CN}^-]$ are governed by $K_a (= 4.9 \times 10^{-10})$.

	HCN	\leftrightarrow	H^+	+	CN^-
initial conc. (M)	0.1		0		0
final conc. (M)	$0.1 - x$		x		x

$$K_a = \frac{[\text{H}^+][\text{CN}^-]}{[\text{HCN}]} = \frac{x^2}{0.1 - x} = 4.9 \times 10^{-10}$$

As x should be far smaller than 0.1, an approximation can be made such that

$$\frac{x^2}{0.1} = 4.9 \times 10^{-10}$$

$$x^2 = 4.9 \times 10^{-11}$$

$[\text{H}^+]$, which is x , is calculated to be 7×10^{-6} M, larger than 10^{-7} M.

Therefore 0.1 M $\text{HCN}(aq)$ is acidic: ① is incorrect.

The larger K_a corresponds to the greater acid strength, and the lower pH for the given concentration. If the concentration is same, $\text{HF}(aq)$ is more acidic and has lower pH than $\text{CH}_3\text{COOH}(aq)$: ② is correct.

In a similar manner to above, $[\text{H}^+]$ is calculated to be $\sqrt{4.9} \times 10^{-5}$ M for 1 M $\text{HCN}(aq)$, and $\sqrt{1.8} \times 10^{-3}$ M for CH_3COOH : ③ is incorrect.

9.

(Answer) A

(Explanation) In figure II, the difference in water levels arises from the osmotic pressure exerted by the solute particles. Depending on the solute type, different numbers of solute particles are released into water, and different extents of osmotic pressure are built. When 0.1 mol of each solute is added to water, following amounts of solute particles will be released:

MgSO_4 : 0.2 mol

CH_3COOH : $(1 + \alpha)/10$ mol ($0 < \alpha < 1$)

CaCl_2 : 0.3 mol

Sugar : 0.1 mol

Therefore, the osmotic pressure will decrease in the order

CaCl_2 solution > MgSO_4 solution > CH_3COOH solution > Sugar solution

**SOLUTION****10.**

(Answer) C

(Explanation) According to *Graham's law**, effusion of H_2 (2 g/mol) will be faster than that of Ne (20 g/mol). The larger size of balloon X than balloon Y, at $t = 1$ h, indicates that effusion occurred more slowly in balloon X. Therefore we can deduce that balloons X and Y initially contained Ne and H_2 , respectively: ① is correct.

The volume contraction from $t = 0$ h to $t = 1$ h is a spontaneous process reflecting that the internal pressure of each balloon was higher than the ambient pressure. From $t = 0$ h to $t = 1$ h, the internal pressure of each balloon continuously decreased toward the ambient pressure. (② is incorrect)

Over the process, gas molecules pass through the balloon, toward an "equilibrium", where all the gaseous species have the equilibrated partial pressures. From $t = 0$ h to $t = 1$ h, not only H_2 and Ne but also the components in air diffuse through the balloon. (③ is correct)

**Graham's law*: The effusion rate of a gas is inversely proportional to the square root of the molar mass.



SOLUTION

[PHYSICS]

11.

(Answer) D

(Explanation) According to the equation of Doppler effect, the frequency that the moth detects is

$$f_{md} = f_{be} \frac{v - v_m}{v - v_b} = 82.5 \frac{340 - 8}{340 - 9} = 82.749 \text{ kHz.}$$

The bat detects a reflected ultrasonic wave from the moth. Therefore, the frequency that the bat detects is

$$f_{bd} = f_{me} \frac{v + v_b}{v + v_m} = 82.749 \frac{340 + 9}{340 + 8} = 82.98 \text{ kHz} \sim 83.0 \text{ kHz}$$

12.

(Answer) B

(Explanation) If object is projected horizontally, the object moves at the constant velocity horizontally and does at the constant acceleration vertically.

From the distance for vertical movement ($H = 20\text{m} = \frac{1}{2}(10\text{m/s}^2)t^2$), one can find the time of

falling is 2 sec. So, the distance for horizontal movement is $D = 10\text{m/s} \times 2\text{sec} = 20\text{m}$.

From the equation of center of mass, one can find the position of the other piece (X),

$$20\text{m} = \frac{0.5\text{kg} \times 10\text{m} + 0.5\text{kg} \times x}{1\text{kg}}$$

$$R = 30\text{m}$$

13.

(Answer) C

(Explanation) Due to the barely circular movement of substance X, the centripetal force at the maximum height should be same as the gravitational force. That is

$$\frac{mv^2}{R} = mg$$

By the conservation of energy, the momentum of X before collision is

$$\frac{1}{2}mv^2 + mg(2R) = \frac{1}{2}mv'^2 \rightarrow mv' = m\sqrt{5gR}, \quad \frac{1}{2}mv'^2 = \frac{5}{2}mgR$$

Since the momentum should be conserved during the collision, the velocity and kinetic energy of X-Y after the collision is

$$3mV = m\sqrt{5gR} \rightarrow V = \frac{1}{3}\sqrt{5gR}, \quad \frac{1}{2}(3m)V^2 = \frac{1}{2}(3m)\frac{1}{9}(5gR) = \frac{1}{3}\left(\frac{1}{2}mv'^2\right)$$

Therefore, the kinetic energy ratio between the kinetic energy of X before collision and that of X-Y after collision, i.e. $K_X/K_{X-Y} = 3$.



SOLUTION

14.

(Answer) B

(Explanation) Because gravity is conservative force, the amount of work is irrelevant to the path.

The amount of work by gravity: mgR (\because moves as much as R by mg)

The amount of work by normal force: 0 (\because Normal force is perpendicular to the moving direction of the object.)

15.

(Answer) C

(Explanation) $\frac{P'V'_A}{3T} = \frac{P'V'_B}{T} \rightarrow V'_A = 3V'_B$

Since the total volume is constant at $2V$,

$$V'_A + V'_B = 2V \rightarrow V'_B = \frac{1}{2}V .$$

From the Boyle - Charles law

$$\frac{PV}{T} = \frac{P'V'_B}{T} \rightarrow P' = 2P$$

16.

(Answer) A

(Explanation) A fish in water appears to be closer than it actually is. As the refractive index of water is $3/4$, the image of fish is located in 30cm to the wall.

By thin lens formula ($\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$), $\frac{1}{10+30} + \frac{1}{10} = \frac{1}{f}$. Therefore, $f = 8\text{cm}$

17.

(Answer) D

(Explanation) A ray of light is refracted on the surface of water like below Figure. By the Snell's law, $n \sin i = \sin r$.

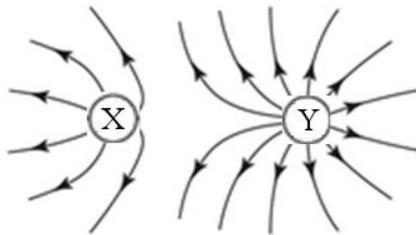
Using $\sin i = \frac{(2H-x)}{\sqrt{(2H-x)^2+H^2}}$, $\sin r = \frac{2H}{\sqrt{(2H)^2+H^2}}$, we can find $x = 2H \left(1 - \frac{1}{\sqrt{5n^2-4}}\right)$.



SOLUTION

18.

(Answer) B



(Explanation) The charges X and Y are the same kind. But the quantity of charge X is less than that of charge Y.

19.

(Answer) C

(Explanation) In a steady state condition, current does not flow along the capacitor. By the Kirchhoff's law (i_1 : the current along 3Ω - 4Ω resistors, i_2 : the current along 4Ω - 2Ω resistors, and i_3 : the current along a 6Ω resistor), $i_2 = i_1 + i_3$, $-8 - 4i_1 - 3i_1 + 12 + 6i_3 = 0$, $-12 + 3i_1 + 4i_1 + 8 + 6i_2 = 0$
So, $i_1 = 0.4A$, $i_2 = 0.2A$, $i_3 = -0.2A$

20.

(Answer) B

(Explanation) By the Lenz's law, P would be N-pole for an approaching magnet and be S-pole for a receding magnet. So we are able to know that the sequence of turn-on of LEDs would be orange-red-blue-yellow from Fleming's right hand rule



[BIOLOGY]

21.

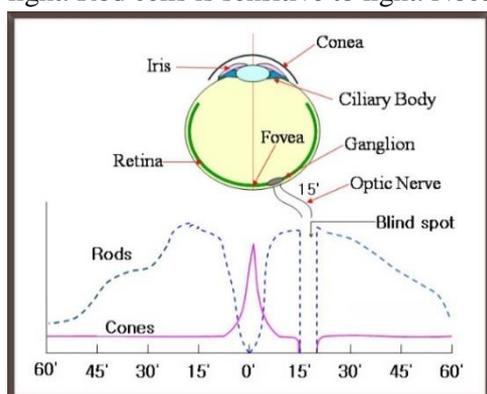
(Answer) D

(Explanation) The nitrogen is fixed to organic nitrogen by bacteria. The organic material is decomposed to ammonia by the bacteria. The process of ammonia to nitrite and nitrate by bacteria is nitrification. Plants are the producer, which uptake NH_4^+ and NO_3^- to synthesize organic materials.

22.

(Answer) D

(Explanation) X is rod cell, and Y is cone cell. Cones distinguish various wavelength of visible light. Rod cells are sensitive to light. Nocturnal animals have more rod cells.



23.

(Answer) A

(Explanation) A binds to base T by two hydrogen bonds and base G to base C with three hydrogen bonds in DNA double strands. Since base ratio of $\text{A}+\text{T}/\text{G}+\text{C} = 1/4$ in given double strands, $\text{A}+\text{T}$ would be 400 bases in DNA double strands ($2000 \times 1/5 = 400$) and $\text{G}+\text{C}$ would be 1600 bases. It indicates that $\text{A}+\text{T}$ and $\text{G}+\text{C}$ are 200 and 800 bases in one strand, respectively. Since mRNA contains 150 U, DNA strand with 150 A should be a template strand, which is strand II. Based on those information, table can be filled out with proper bases as shown below

		Base composition (number)					
		G	A	T	C	U	Sum
DNA	I	500	50	150	300	-	1000
	II	300	150	50	500	-	1000
mRNA		500	50	150	(300)	150	1000

**24.**

(Answer) A

(Explanation) The first polar body is attached to ovulated egg and the two second polar bodies will be formed after fertilization occurred. Thus three polar bodies will be found attached to egg after and fertilization occurred and then meiosis completed. Corpus luteum produces estrogen and progesterone. Each blastomere as a human cell has 46 chromosomes. At the time of implantation, zygote is at the stage of blastocyst.

25.

(Answer) B

(Explanation) In a first experiment, flies respond to gravity but not to red light, and in a second experiment, flies respond to both blue light and gravity. Tube II and IV were served as controls for the gravity variable.

26. .

(Answer) A

(Explanation) The valves in the vein prevent reverse flow and make blood flows to heart smooth. The surrounding muscles near the veins help this mechanism. In this figure contracted muscles squeeze the vein to help the blood flow from Y to X. So the blood pressure at Y is higher than at X to make the blood flow well when the muscles contract. When the muscles relaxed, the valve opening between Y and Z makes blood flow from Z to Y as normal.

27.

(Answer) B

(Explanation) For secondary immune response, when the same antigen again invade in the body, the memory cells are differentiated into plasma cells, and produce large amounts of antibodies within a short time.

28.

(Answer) C

(Explanation) Highly condensed chromosome are formed in metaphase in cell cycle. Allele is gene that is found at same site on homologous chromosome. Nucleosome is basic unit of chromosome and consists of histone octamer and ~200 bp DNA. Bacteria have circular DNA that does not contain histone protein.

29.

(Answer) A

(Explanation) As natural selection works on a population, the gene pool changes. The favorable adaptations become more plentiful and the less desirable traits become fewer or even disappear from the gene pool completely.



SOLUTION

Directional selection (I): a mode of natural selection in which a single phenotype is favored, causing the allele frequency to continuously shift in one direction. The genetic variance of the population shifts toward a new phenotype when exposed to environmental changes. In the case of such selection, the mean of the population graph shifts. Using the familiar example of giraffe necks, there was a selection pressure against short necks, since individuals with short necks could not reach as many leaves on which to feed. As a result, the distribution of neck length shifted to favor individuals with long necks. Another example, light-colored peppered moths are better camouflaged against a pristine environment, and dark-colored are better camouflaged against a sooty environment. Thus, as Industrial Revolution progressed in nineteenth-century England, the color of the moth population shifted from light to dark. (resistance).

Disruptive Selection (II): a mode of natural selection in which extreme values for a trait are favored over intermediate values. The genetic variance of the population increases when natural selection selects for two or more extreme phenotypes that each have specific advantages. For example, imagine a plant of extremely variable height that is pollinated by three different pollinators, one that was attracted to short plants, another that preferred plants of medium height and a third that visited only the tallest plants. If the pollinator that preferred plants of medium height disappeared from an area, medium height plants would be selected against and the population would tend toward both short and tall, but not medium height plants. (Multi-niche)

Stabilizing selection (III): a type of natural selection in which genetic diversity decreases as the population stabilizes on a particular trait value. The genetic variance of the population decreases when natural selection favors an average phenotype and selects against extreme variations. Robins typically lay four eggs. Larger clutches may result in malnourished chicks, while smaller clutches may result in no viable offspring. (tolerance)

Directional or disruptive selection: One of the best-studied examples of directional selection is the peppered moth in England. The moth gets its name from the peppery-looking coloration on its wings and body. The peppered moth may be a light color or a dark color, with very few individuals being a color in between the two extremes.

30.

(Answer) D

(Explanation) I is a plant cell. II is an animal cell. III is a bacterial cell. There are cell walls in plant and bacterial cell. There is no nuclear envelope (membrane) in bacteria cell. Organelle X is chloroplast and organelle Y is mitochondria. Both have DNA, which is genetic material.