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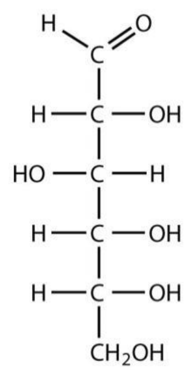
Sample Question Solutions for the Individual Round Test

1. Glucose is the most basic sugar involved in human metabolism. Its structure is provided below



a. The overall reaction of glucose metabolism is given below.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

i. Provide oxidation numbers of the following atoms in particular molecules.

Carbon in Glucose ($C_6H_{12}O_6$)	0
Oxygen in O_2	0
Oxygen in CO_2	-2
Carbon in CO_2	+4

ii. Of the two reactants, which one is the reducing agent and which one is oxidizing agent?

Oxidizing Agent: O_2

Reducing Agent: $C_6H_{12}O_6$

iii. According to the American Heart Association, the maximum amount of added sugars the average man should digest in one day is 37.5 g. Assuming all of this sugar is in the form of glucose, how many electrons are transferred from the reducing agent to the oxidizing agent?

Given 1 mole of $C_6H_{12}O_6$ and 6 moles of O_2, 6 moles of carbon atoms are oxidized from an oxidation state of 0 to an oxidation state of +4. So, 4 moles of electrons are oxidized from every mole of carbon atoms ($\frac{4\ moles\ of\ electrons}{1\ mole\ of\ carbon\ atoms}$).

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For 1 mole, of $C_6H_{12}O_6$,

$$1\ mole\ of\ glucose * \frac{6\ moles\ of\ carbon\ atoms}{1\ mole\ of\ glucose} * \frac{4\ moles\ of\ electrons}{1\ mole\ of\ carbon\ atoms} = 24\ moles\ of\ electrons$$

With 37.5g of $C_6H_{12}O_6$,

$$37.5g\ C_6H_{12}O_6 * \frac{1\ mole\ C_6H_{12}O_6}{180.216g} = 0.208\ moles\ of\ C_6H_{12}O_6$$

$$0.208\ moles\ of\ C_6H_{12}O_6 * \frac{24\ moles\ of\ electrons}{1\ mole\ of\ C_6H_{12}O_6} * \frac{6.022 * 10^{23}\ electrons}{1\ mole\ of\ electrons} = 3.00 * 10^{24} electrons$$

b. The first step of glucose metabolism is the phosphorylation of glucose. In this reaction, glucose is reacted with ATP to produce glucose – 6 – phosphate.

i. The net balanced equation for glucose phosphorylation is provided below. Given that ΔG for this reaction at 25°C is 13.8kJ/mol, determine K_c of the forward direction.

$$\nabla G = -RTln(K_c) = -\left(\frac{8.314J}{molK}\right) * (25 + 273)K * \ln(K_c) = \frac{13.8kJ}{mol}$$

$$K_c = e^{(\frac{13.8kJ}{mol} * \frac{1000J}{kJ})(-\frac{8.314J}{molK} * (25+273)K)} = 0.00381$$

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ii. The ΔG value given in part b(i) was determined at pH 7.0 and 25°C. Given the following heats of formation, how many moles of glucose-6-phosphate are produced at 30°C starting with 1 mole of glucose and 1 mole of ATP?

$$\Delta H_{rxn} = \sum \Delta H_f(products) - \sum \Delta H_f(reactants)$$
$$= \left(-\frac{2000kJ}{mol} + \left(-\frac{780kJ}{mol}\right)\right) - \left(-\left(\frac{2982kJ}{mol}\right) + \left(-\frac{1268kJ}{mol}\right)\right)$$
$$= \frac{1470kJ}{mol}$$
$$\ln\frac{K_2}{0.00381} = \frac{-\frac{1470kJ}{mol} * \frac{1000J}{kJ}}{\frac{8.314J}{molK}} * \left(\frac{1}{(30+273)K} - \frac{1}{(25+273)K}\right)$$
$$K_2 = 68.08 = \frac{[ADP][C_6H_{13}O_9]}{[ATP][C_6H_{12}O_9]}$$

Let x represent the amount of $C_6H_{13}O_9$ or ADP produced.

$$K_2 = 68.08 = \frac{[ADP][C_6H_{13}O_9]}{[ATP][C_6H_{12}O_9]} = \frac{[x][x]}{[1-x][1-x]}$$
$$68.08[1-x]^2 = [x]^2$$
$$68.08 - 136.16x + 68.08x^2 = x^2$$
$$68.08 - 136.16x + 67.08x^2 = 0$$

Using the quadratic formula, $x = 1.14\ moles\ or\ 0.89\ moles$

However, $x \neq 1.14\ moles$ because, given 1 mole of each reactant, a maximum of 1 mole of each product can be formed.

Therefore, approximately 0.89 moles of glucose-6-phosphate are produced.

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2. A salt is an ionic compound formed when a metal cation replaces the hydrogen atom of an acid.

a. Certain metal can be identified by a flame test in which the metal ions emit a specific color when they are heated. These colors are the result of excited electrons transitioning back to their stable ground state and releasing that energy in the form of light of a specific wavelength when these ions are heated. A chart of the flame test colors for specific metals is listed below. Which metal emits light of the highest energy?

Metal	**Flame Color**
Sodium	Yellow
Calcium	Orange
Lithium	Red
Copper	Green
Lead	Blue

The energy of a photon of light $E_{ph} = h\nu = h(\frac{c}{\lambda})$. From this equation, it is apparent that a greater wavelength of light corresponds to a lower energy photon.

Therefore, lead emits the light of the highest energy since blue light is on the high frequency or low wavelength end of the visible light spectrum compared to the colors of the other flames in this table.

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b. The Electromagnetic radiation, like the light you see in a flame test, is composed of photons. Calculate the wavelength of a photon with energy of 2.098 x 10^{-19} J in nanometers. Then identify the color of the photon using the chart provided below.

Color	**Wavelength(nm)**
Red	700-635
Orange	635-590
Yellow	590-560
Green	560-520
Cyan	520-490
Blue	490-450
Purple	450-400

$E_{ph} = h\nu = h(\frac{c}{\lambda})$ where λ is the wavelength of the photon in meters.

$$E_{ph} = 2.098 \times 10^{-19} J = \frac{1.986 \times 10^{-25} J{\cdot}m}{\lambda}$$

$$\lambda = \frac{1.986 \times 10^{-25} J{\cdot}m}{2.098 \times 10^{-19} J} = 9.47 \times 10^{-7} m = 947\ nm$$

Since the visible light spectrum spans from just under $400 nm$ to $700 nm$, photons of this energy would not be perceived as visible light of any color by humans.

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c. By a process known as selective precipitation, ions in solution can be separated based on their solubility. An aqueous solution of lithium chloride is slowly added to another aqueous solution of 1.30×10^{-4}M barium ions, 9.80×10^{-2}M lead (II) ions, and 7.90×10^{-5}M copper (I) ions at $25°$□. Determine the order in which the three chloride salts will precipitate. The K_{sp}'s of these salts are provided below.

Salt	K_{sp}
Copper Chloride	1.70×10^{-7}
Barium Chloride	2.60×10^{-9},
Lead Chloride	1.20×10^{-5}, a

For $BaCl_2$, $K_{sp} = [Ba^{2+}][Cl^-]^2 = 2.60 \times 10^{-9}$.The amount of chloride ion needed for $BaCl_2$ to precipitate = $\sqrt{\frac{2.60 \times 10^{-9}}{1.30 \times 10^{-4}}} = 4.47 \times 10^{-3} M$.

For $PbCl_2$, $K_{sp} = [Pb^{2+}][Cl^-]^2 = 1.20 \times 10^{-5}$.The amount of chlorine ion needed for $PbCl_2$ to precipitate = $\sqrt{\frac{1.20 \times 10^{-5}}{9.80 \times 10^{-2}}} = 1.11 \times 10^{-2} M$.

For $CuCl$, $K_{sp} = [Cu^+][Cl^-] = 1.70 \times 10^{-7}$.The amount of chlorine ion needed for $CuCl$ to precipitate = $\frac{1.70 \times 10^{-7}}{7.90 \times 10^{-5}} = 2.15 \times 10^{-3} M$.

Comparing the chloride ion concentrations needed for the 3 chloride compounds to precipitate: $2.15 \times 10^{-3} M < 4.47 \times 10^{-3} M < 1.11 \times 10^{-2} M$
$CuCl$ will precipitate first, $BaCl_2$ precipitates next, and $PbCl_2$ precipitates last.

d. If the salt that precipitated out first in part c was dissolved in pure water, would the solution be acidic or basic?

The compound that precipitated first in part (c) was $CuCl$. In a neutralization reaction between an acid and a base that formed this compound, the acid would be HCl, a strong acid. The base that it would have to pair with to form $CuCl$ in a neutralization reaction is $CuOH$. Since copper (I) hydroxide is a weak base, $CuCl$ should be considered an acidic salt, not a neutral salt.
The same logic can be used if it is assumed that the compound that precipitated first in part (c) was $PbCl_2$. The base that would neutralize the strong acid HCl in this neutralization reaction is $Pb(OH)_2$, another weak base. Therefore, $PbCl_2$ is also an acidic salt, not a neutral salt.

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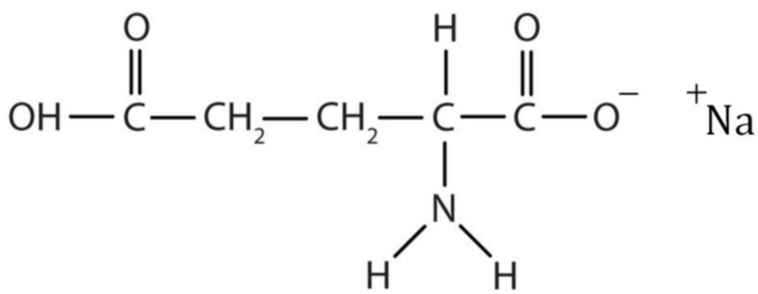
3. 1. 5 out of 5 doctors recommend that humans should not consume Uranium, but rather recommend eating healthier foods such as apples or Broccoli. One substance with health effects that are much more controversial is monosodium glutamate, or as it is more commonly known, MSG. MSG is commonly used by people to add a savory flavor to foods, but people have gone as far call it a “silent killer”.

a. Below is the structure of MSG. How many atoms are sp^3 hybridized? Sp^2? Sp?



There are 6 sp^3 hybridized atoms, 4 sp^2 hybridized atoms and 0 sp hybridized atoms.

b. What is the VSEPR predicted geometry around the nitrogen atom of the amine group ($-NH_2$)? How does the Carbon-Nitrogen-Hydrogen of the Amine group compare to the Hydrogen-Carbon-Hydrogen bond of Methane (CH_4)? How does the molecular geometry of the groups compare?

The geometry around the amine nitrogen is tetrahedral. The geometry of the amine group is the same as that of methane, but the hydrogen-nitrogen-carbon angle would be smaller, because the lone pair on the nitrogen has more electron repulsion.

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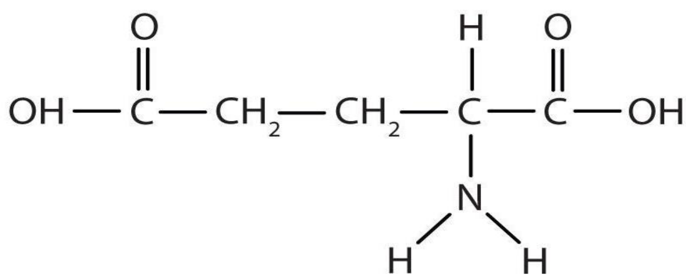
c. The reason MSG is an effective flavor enhancer is that it mimics the amino acid Glutamate, and binds similar receptors. Glutamate is released from the breakdown of meat. The structure of glutamate is shown below. Why is MSG able to effectively activate glutamate receptors?



The structure of MSG is very similar to glutamate, so it would be able to bind to and activate glutamate receptors.

d. Name the general reaction type by which glutamate is converted into monosodium glutamate

Neutralization Reaction

e. If equimolar amounts of MSG and glutamate were placed into separate glasses each containing equal amounts of water, which solution would have the higher boiling point

The MSG solution would have the higher boiling point, because more species are produced from the dissolution of MSG