

Theoretical Competition

**– Solution –**

December 6, 2015

**I. Chemical Oxygen Demand (COD) Test**

**I-1**

**I-1-1 [0.5 points]**

(Answer) *a* + *b*/4 − *c*/2

(Explanation) Balance the masses of O for both sides.

*c* + 2*x* = 2*a* + 0.5*b* **[0.3 points]**

*x* = *a* + 0.25*b* − 0.5*c* **[0.2 points]**

**I-1-2. [0.5 points]**

(Answer) 8*y*

(Explanation) Balance the charges for both sides.

(−2)*y +* (+1)*z* = 2*y*(+3) **[0.3 points]**

*z* = 8*y* **[0.2 points]**

**I-1-3. [0.5 points]**

(Answer) 2*a*/3 + *b*/6 − *c*/3

(Explanation)

Balance the masses of O.

*c* + 7*y* = 2*a* + 0.5*b* + 0.5*z* **[0.2 points]**

Substitute 8*y* for z

3*y* = 2*a* + 0.5*b* − *c* **[0.2 points]**

*y* = 2*a*/3 + *b*/6 − *c*/3 **[0.1 points]**

**I-1-4. [0.5 points]**

(Answer) 3*y*/2

(Explanation)

From the former questions,

*x* = *a* + *b*/4− *c*/2 **[0.1 points]**

*y* = 2*a*/3 + *b*/6 − *c*/3 = (2/3) × (*a* + *b*/4− *c*/2) **[0.2 points]**

Therefore, *x* = 3*y*/2 **[0.2 points]**

**I-2**

**I-2-1. [1.0 point]**

(Answer) 6

(Explanation)

(Method 1) Balance the charge sums on both sides.

−2 + 2*f* +14 = +6 + 3*f* **[0.5 points]**

*f* = 6 **[0.5 points]**

(Method 2) The electron flows for the redox pairs can be compared

Oxidation) *f* Fe2+ → *f* Fe3+ + *f* *e*− number of electrons released: *f* **[0.2 points]**

Reduction) Cr2O72− + 6*e*− → 2Cr3+ number of electrons consumed: 6 **[0.3 points]**

*f* = 6 **[0.5 points]**

**I-2-2. [1.0 point]**

(Answer) 

(Explanation)

The titration in the step (B) involves the redox reaction of Fe and Cr.

(unbalanced)

As the reduction of Cr2O72− (Cr6+) to 2Cr3+ has to be coupled by oxidation of 6Fe2+ → 6Fe3+, titration of Cr2O72− requires 6 equivalents of Fe2+. **[0.2 points]**

That is, at the beginning of step (B), the amount of K2Cr2O7 was (1.20 × 10−3)/6 = 2.00 × 10−4 mol. **[0.5 points]**

So, 6.0 × 10−5 (= 2.60 × 10−4 - 2.00 × 10−4 )mol of K2Cr2O7 had been consumed for oxidizing pollutants. **[0.3 points]**

**I-2-3. [1.0 point]**

(Answer) 288

(Explanation)

6.0 × 10−5 mol of K2Cr2O7 were required to treat 10.0 mL of waste water.

Thus, 1.00 L of waste water should require 6.0 × 10−3 mol of K2Cr2O7. **[0.2 points]**

Equivalently this corresponds to 9.0 × 10−3 mol (=6.0 × 10−3 mol × 3/2) **[0.3 points]** and 0.288 g (9.0 × 10−3 mol × 32) = 288 mg of O2 **[0.3 points]**.

Then, the COD can be expressed as 288 ppm. **[0.2 points]**

**I-2-4. [2.0 points]**

(Answer) 93.6, 0.176

(Explanation)

1 mole of C6H6 can be fully decomposed by 7.5 moles of O2.

Or express chemical equation. **[0.3 points]**

So, 9.0 × 10−3 mol of O2 corresponds to 9.0 × 10−3 mol/7.5 = 1.2 × 10−3 mol **[0.3 points]**

**[0.4 points]**

1 mole of C6H6 is decomposed to 6 moles of CO2. **[0.2 points]**

Therefore in the present case, 7.2 × 10−3 moles (= 1.2 × 10−3 mol × 6) of CO2 are evolved. **[0.3 points]**

CO2 volume is calculated as followed:

**[0.2 points]**

**[0.3 points]**

**I-2-5. [1.0 point]**

(Answer) 1.2 × 10−4, 5.2 × 10−4

(Explanation)

Initially, there were 2.60 × 10−4 moles of Cr2O72− but no Cr3+ in the test system. **[0.1 points]**

From the results of titration with Fe2+, we figure that 2.00 × 10−4 moles of Cr2O72− were present at the beginning of step (B), which means that 0.60 × 10−4 moles of Cr2O72− were used to decompose the pollutant and to produce the 1.20 × 10−4 (=0.60 × 10−4 × 2) moles of Cr3+ before the Fe2+ titration. **[0.4 points]**

In the step (B), 2.00 × 10−4 moles of Cr2O72− were used and 4.00 × 10−4 (=2.00 × 10−4 × 2) moles of Cr3+ ions produced. **[0.3 points]**

Therefore the concentration of Cr3+ ions after Fe2+ titration is 5.20 × 10−4 (=4.00 × 10−4 +1.20 × 10−4) moles. **[0.2 points]**

|  |  |  |
| --- | --- | --- |
|  | Amounts present | |
| Cr2O72− | Cr3+ |
| Initial | 2.60 × 10−4 mol | 0 |
| Change during step (A) | − 0.60 × 10−4 mol | + 1.2 × 10−4 mol |
| After step (A)/ Before step (B) | 2.00 × 10−4 mol | 1.2 × 10−4 mol |
| Change during step (B) | − 2.00 × 10−4 mol | + 4.00 × 10−4 mol |
| After step (B) | 0 | 5.2 × 10−4 mol |

**I-3. [2.0 points]**

(Answer) CH3CHO, 18

(Explanation) Based on equation (1), oxidation of each pollutant requires following amount of O2.

**[0.3 points, each 0.1 points]**

The COD of the pollutant solutions can be calculated stepwise,

|  |  |  |  |
| --- | --- | --- | --- |
|  | Moles of O2 per  1 mole pollutant | Moles of O2 per  10.0 mg pollutant  **[0.6 points]**  **= [each 0.2 point]** | COD for 10.0 mg/L  pollutant solution  **[0.9 points]**  **= [each 0.3 point]** |
| HCOOH  (46 g/mol) | 0.5 | 0.5 × (10.0 × 10−3)/46 | 32 × 103 × 0.5 × (10.0 × 10−3)/46  = 3.5 ppm |
| CH3OH  (32 g/mol) | 1.5 | 1.5 × (10.0 × 10−3)/32 | 32 × 103 × 1.5 × (10.0 × 10−3)/32  = 15 ppm |
| CH3CHO  (44 g/mol) | 2.5 | 2.5 × (10.0 × 10−3)/44 | 32 × 103 × 2.5 × (10.0 × 10−3)/44  = 18 ppm |

Of the three samples, CH3CHO solution has the highest COD **[0.1 points]**, which is 18 ppm. **[0.1 points]**

**In any case, student who make correct answer (CH3CHO and 18 ppm), will have full credits.**

**II. Ski Jumping**

**II-1 [0.75 points] [**Correct answer: 0.25, wrong answer: 0 for each force]

(Answer) Gravitational force ⑤, Normal force ②, Air resistance ⑧

**II-2 [1.5 point]**

(Answer) (Explanation) By conservation of energy [1.0] or dynamitic & kinematic [0.5 + 0.5 or proportional rating for any other method]

[0.5]

**II-3 [1.5 point]**

(Answer)

(Explanation) The horizontal distance to the landing point is . [0.5]

The vertical distance to the landing point is *.* [0.5]

Or proportional rating for any other method

From , we can find *.* [possible 0.25 for using ratio in slope + 0,25 rearranging the equation]

**II-4 [1.25 point]**

(Answer) [0.25 final answer]

(Explanation)

[0.5 + 0.5 for any method steps]

**III. Thomson’s Cathode-Ray Experiment**

**III-1 [1.0 point]**

(Answer)

(Explanation) Potential energy of the electron at L1 is [0.25]. At the moment of electron passing through a slit of M1, kinetic energy of the electron at M1 is [0.25], all of the potential energy converts to the kinetic energy [0.25].

[0.25]

**III-2.**

**III-2-1. [1.0 point]** (Correct answer: 1 point, wrong answer: 0 point)

(Answer) ①

(Explanation) The electric force exerts on the electron. Because the charge of the electron is negative, the electric force exerts to the M2 direction. So the trace of the electron is ①.

**III-2-2. [1.0 point]** (Correct answer: 1 point, wrong answer: 0 point)

(Answer) ③

(Explanation) The magnetic force exerts on the electron. Because the negative electron moves to the right and the magnetic field points into the page, the magnetic force exerts to the L2 direction. So the trace of the electron is ③.

**III-3 [1.5 point]**

(Answer)

(Explanation) When the electron flies straight (trace ②), the electric force directed to M2 and the magnetic force directed to L2 are compensated with the same magnitude ( or 0.5 point). Then, . [0.5] The speed of the electron is . [0.5]

**III-4 [0.5 point]**

(Answer)

(Explanation) (0.25 point for )

(0.25 point for rearranging the formula)

**IV. Excretory System**

(Explanation) The blood arrives through the renal artery and leaves in the renal vein. The kidneys produce urine which is carried to the bladder along the ureter. There are three major anatomical demarcations in the kidney: the cortex, the medulla, and the renal pelvis. The cortex receives most of the blood flow, and is mostly concerned with reabsorbing filtered material.

X is protein. Y is glucose. Z is urea. Water is filtered from the glomerulus to the Bowman’s capsule and re-absorbed, and discharged to form urine. Urea is the substance to be filtered, so is in both the plasma and the filtrate. Glucoses and amino acids are filtered, and 100%re-absorbed. Proteins are not filtered.

**IV-1.[1.0 points]**

(Answer)

|  |  |
| --- | --- |
| **I-1** | **( 1 )** |

**IV-2.[1.5 points]= 3 x 0.5 points**

(Answer)

|  |  |  |
| --- | --- | --- |
| (X) | (Y) | (Z) |
| ( 0.0 )g/100mL | ( 0.1 )g/100mL | ( 0.0 )g/100mL |
|

unit (g/100mL)

|  |  |  |  |
| --- | --- | --- | --- |
| constituent | Blood plasma | Primitive urine | urine |
| Water | 92-93 | 92 | 95 |
| Urea (Z) | 0.03 | 0.03 | 2.00 |
| Uric acid | 0.004 | 0.004 | 0.05 |
| Glucose (Y) | 0.1 | 0.1 | 0 |
| Amino acids | 0.005 | 0.005 | 0 |
| Minerals | 0.9 | 0.9 | 0.9-3.6 |
| Proteins (X) | 8.0 | 0 | 0 |

**IV-3.[1.5 points]= 3x 0.5 points**

(Answer)

|  |  |  |
| --- | --- | --- |
| (X) | (Y) | (Z) |
| III | I, II  Alternatives  Only I or II: (0.25 points)  Other: (0 point) | II |
|

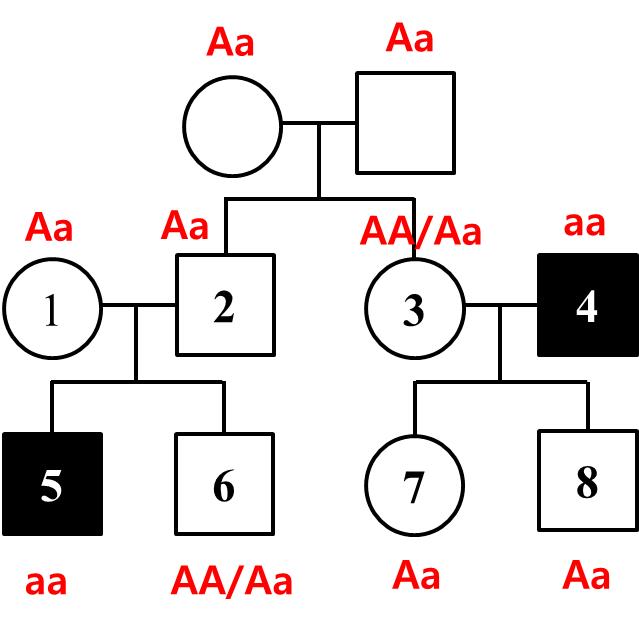
**V. Genetics**

(Answer)

|  |  |  |
| --- | --- | --- |
| V-1 | V-2 | V-3 |
| 6 | 1/8 | 5’ -----TAAGGTCA-----3’ |

(Explanation)

**V-1.[1.0 point]**The answer is autosomal recessive. Because the individual 4 is an affected male, his genotype should be homo-recessive (aa). Thus, his offspring has to have at least one recessive allele. That is, although individuals 7 and 8 are both phenotypically normal, they have a mutant allele, respectively.



**V-2. [1.0 point]**Since individuals 1 and 2 already have an affected child, they must be heterozygotes. Aa x Aa 🡪AA, Aa, Aa, aa. Therefore, the probability that anew born female will be affected is 1/8 (1/4 x 1/2).

(1 point) for the correct answer

(1 point) for zero probability, if the answer to V-1 was 2

(0 point) for other options

**V-3. [1.0 point]**The nucleotide ‘C’ in[5’----**TACGGTCA**----3’] from the wild type has been replaced to ‘A’in the mutant allele, making [5’----TA**AGGTCA**----3’].

**VI. Blood Circulation**

**VI-1.[1.0 point]= 4 x 0.25 points**

(Answer)

|  |  |  |
| --- | --- | --- |
|  | Semilunar valves | Atrioventricular valves |
| *t1* | Opened (**○**) | Closed(**×**) |
| *t2*, | Closed (**×**) | Opened(**○**) |

(Explanation)Atrioventricular valves (AV valves) are thin flaps of tissue between the atria and ventricles. Semilunar valves lie at the openings from the ventricles into the arteries and prevent blood pumped out of the heart from returning to it. At *t1* of ventricle contraction, AV valves are closed while semilunar valves are opened. At *t2* of ventricle relaxation, semilunar valves are closed while AV valves are opened to fill ventricle out with blood.

**VI-2.[1.0 point]**

(Answer)

|  |  |
| --- | --- |
| Heart rate | ( 75 ) beats/min |

(Explanation)Heart rate is beating number of heart per unit time (min). Referring to the graph, the second heartbeat comes in 0.8 sec after the first heartbeat.

∴Heart rate = X = 75 beats/min

(1 points) for the correct answer

(0.5 points) for the correct calculation, if the answer is not correct

**VI-3.[1.0 point]**

(Answer)

|  |  |
| --- | --- |
| Cardiac output | ( 5.25) L/min |

(Explanation)Cardiac output is defined as the volume of blood pumped per ventricle per unit time. It can be calculated by multiplying heart rate (beats per min) by stroke volume (mL/beat)

Cardiac output = heart rate X stroke volume

Stroke volume = Volume of blood before contraction - Volume of blood after contraction

By graph, stroke volume = 135 mL – 65 mL = 70 mL

∴ Cardiac output = 75 beats/min x 70 mL/beat = 5250 mL/min (5.25 L/min)

(1 points) for the correct answer, according to the answer of the question VI.2

(0.5 points) for the correct calculation, if the answer is not correct