IJSO 2021 Chemistry Theory solution set

Solution: Q.1.1 **2M**

Since the reaction is of first order with respect to sucrose,

Rate constant $k=(2.303/t)^* \log a/a-x$

$k_{303K} = \frac{2.303}{600} \log \frac{\{12.5 - (-15.5)\}}{\{(-3.0) - (-15.5)\}}$

$= \frac{2.303}{600} \log \frac{28.0}{12.5} =$ **$1.344 \times 10^{-3}\ s^{-1}$** **(0.5 M)**

$k_{311K} = \frac{2.303}{600} \log \frac{\{12.5 - (-15.5)\}}{\{(-8.0) - (-15.5)\}}$

$= \frac{2.303}{600} \log \frac{28.0}{7.5} =$ **$2.187 \times 10^{-3} s^{-1}$** **(0.5 M)**

Arrhenius eqn: $\log \frac{k_{311}}{k_{303}} = \frac{E}{2.303\ R} \frac{\{T_2 - T_1\}}{\{T_1 T_2\}}$

$\log \frac{2.187 \times 10^{-3}}{1.344 \times 10^{-3}} = \frac{E}{2.303 \times 8.314} \frac{\{311 - 303\}}{\{311 \times 303\}}$

$\log 1.627 = \frac{E}{2.303 \times 8.314} \frac{\{8\}}{\{311 \times 303\}}$

$E = 47.66$ kJ mol^{-1} **(1.0M)**

Deduct 0.25 Marks, if correct units are not written.

Solution:1.2 **1M**

Arrhenius equation $\log k = \log A - E/2.303\ RT$

$T = 27 + 273 = 300K$

$R = 8.314 \times 10^{-3}$ kJ K^{-1}mol^{-1}

When $E = 60$ kJ mol^{-1}, $\log k_2 = \log A - 60/2.303\ (8.314 \times 10^{-3})\ 300$

When $E = 66$ kJ mol^{-1}, $\log k_1 = \log A - 66/2.303(8.314 \times 10^{-3})\ 300$

Subtracting we get,

$\log k_2 - \log k_1 = [-60 - (-66)]/2.303(8.314 \times 10^{-3})\ 300$

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$= 6/2.303\ (8.3 \times 10^{-3})\ 300$

$= 1.0463$

$\log k_2/k_1$ = 1.0677 (0.75M)

Therefore k_2/k_1 = 11.66 (0.25M)

Solution:

1.3 2Marks

(A) : $CuCO_3$ (B) :CuS (C) : $Cu(NO_3)_2$ D: $Cu(OH)_2$ **(0.25 marks for each correct identification)**

Reactions:

$CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$

A

$CuCl_2 + H_2S \rightarrow CuS + 2\ HCl$

B

$3\ CuS + 8\ HNO_3 \rightarrow 3\ Cu(NO_3)_2 + 2\ NO + 3\ S + 4\ H_2O$

C

$Cu(NO_3)_2 + 2\ NaOH \rightarrow Cu(OH)_2 + 2\ NaNO_3$

D

(0.25 marks for each correctly balanced reaction)

Soluion Q.2

2.1) 1 lit/min for 15 mins 4 times = 60 lit
21% of oxygen = 100 % air
60 lit of oxygen = (60/21) X 100 = **286 lit** **(0.5M)**
(Deduct 0.25 marks if correct unit is not written)

2.2) For getting 60 lit of oxygen

$2H_2O \rightarrow 2H_2 + O_2$

22.4 lit of oxygen = 1 mol O_2 = 2 mol water = 36 g= 36 mL of water

60 lit of oxygen = (60 x 36)/22.4 = **96.43 mL of water** **(0.5M)**

(Deduct 0.25 marks if correct unit is not written)

2.3) $P_1V_1 = P_2V_2$

Available oxygen: 340 L, 13700 kPa

Required at 101.3 kPa

V_2 = (340 x 13700) / 101.3 = **45982 L** **(0.25 M)**

Required rate: 5 L /min

Hence 45982 L available for 9196 min

= 9196/60 = 153 hrs = 6.38 days

Fresh supply needed after 6 days **(0.25 M)**

2.4) **1.5M**

P V = nRT or n = PV/RT = 1 x 2840 / (0.0821 x 303)

n = 114 mol **(0.25M)**

n = 114 mole CO_2= 114 x 44 g CO_2

$CaCO_3 \rightarrow CaO + CO_2$
100g 44g

Required 114 x 44 **= 5016g CO_2** **(0.5M)**
(Deduct 0.25 marks if correct unit is not written)
100 x 5016 /44 g $CaCO_3$

But limestone contains 80% $CaCO_3$

100 g limestone = 80 g $CaCO_3$

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Hence limestone reqd= (100 x 100 x 5016) / (44 x 80)

= 14250g = **14.25 kg** **(0.25M)**

KE = (3/2) n R T = (3/2) x 114 x 8.314 x 303 joules

= 4.31×10^5 joules = **431kJ** **(0.5M)**

(Deduct 0.25 marks if correct unit is not written)

2.5) **1M**

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

6 moles O_2reqd per mole of glucose

6 X 22.4 lit of oxygen at STP is required for 1 mole of glucose = 134.4 lit of oxygen at STP **(0.25M)**

$P_1V_1 / T_1 = P_2V_2 / T_2$

V_2 = (1 x 134.4 x 303) / 273 = **149.17 L** at 30°C **(0.5M)**

6 moles of oxygen = **192 g** **(0.25 M)**

2.6) **1M**

Let the volume of the gases be a.

rate of diffusion of oxygen = a/3600

$\frac{\text{time taken for } CO_2}{3600} = \sqrt{(44/32)} = \sqrt{1.375} = 1.173$

Time taken for CO_2 = 3600 x 1.173 =**4223 s** **(0.5)**

(Deduct 0.25 marks if correct unit is not written)

Similarly, time taken for Cl_2 = 3600 √ (71/32) = 3600 x 1.489 = **5360.4 s** **(0.5M)**