Answers

Needed constants
1 u = 1.66 x 10^{-27} kg
1eV = 1.602 x 10^{-19}J

Solution

1.1 Mass defect = 4 × 1.00794 – 4.002602
= 0.029158 u (0.2 mark)
= 0.029158 × 1.66 x 10^{-27} kg (0.05 mark)
= 4.8402 x 10^{-29} kg (0.05 mark)

(0.3 mark)

Energy released = Mass defect × (speed of light)^2 (0.1 mark)
= 4.8402 × 10^{-29} × (3.0 × 10^8)^2 J (0.1)
= 4.356 x 10^{-12} (0.2)

(0.4 mark)

1.2 Total power out of the sun's surface = total power received at a distance R on the earth, (0.5)
ie. $4\pi r^2 E = 4\pi R^2 S_o$ (0.5)
where E is the power per unit surface area of the sun, and S_o is the solar constant, r and R are the radius of the sun and the mean distance between the earth and the sun, respectively.
Thus,

$$S_o = \left(\frac{r}{R}\right)^2 E \qquad (0.3)$$

$$= 5.7\times10^{-8}\times(5800)^4\times\left(\frac{7.0\times10^5\times10^3}{1.5\times10^8\times10^3}\right)^2 = 1404.75 Wm^{-2} \qquad (0.3)$$

(1.6 marks)

1.3
$$Time = \frac{\text{Mean earth - sun distance}}{\text{speed of light}} \qquad (0.3)$$

$$= \frac{1.5\times10^{11}}{3.0\times10^8\times60} = 8.33\text{mins} \qquad (0.2)$$

(0.5 mark)

1.4 Given that

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$$ ***(0.3 mark)***

Substituting,

$$\lambda = \frac{6.62\times10^{-34}\times3.0\times10^{8}}{2.42\times1.602\times10^{-19}} \quad (0.2)$$

$$= 5.14\times10^{-7}\,m \quad (0.1)$$

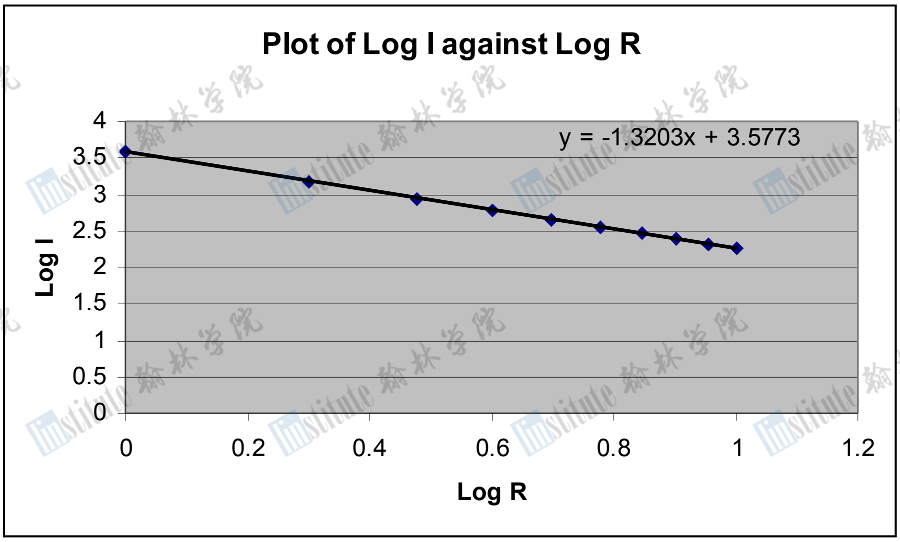
1.5 $\log_{10} S = \log_{10}\beta - \alpha \log R$ (0.4)

1.6 Table of Values

Insolation(I) (Wm^{-2})	Resistance(R) (Ohms)	log I	log R
3777	1	3.577	0.000
1513	2	3.180	0.301
886	3	2.947	0.477
606	4	2.782	0.602
451	5	2.654	0.699
355	6	2.550	0.778
290	7	2.462	0.845
243	8	2.386	0.903
208	9	2.318	0.954
180	10	2.255	1.000

(0.1 for each correct value)

(2 marks)



(0.2 for each accurately plotted point)

(0.2 for axis labelling, and 0.3 for good scale)

(2.5 marks)

1.7 Equation of the graph plotted

$Log_{10} S = 3.5773 - 1.3203 \log_{10}R$ (1.0)

1.8 $\alpha = 1.3203$ (0.4)

$\log \beta = 3.5773$ (0.2)

$\beta = 10^{3.5773}$ (0.2)

$= 3778$ (0.2)

2.1 Choose the two correct options from A-F, why it is not commercially suitable to dissolve SO_3 directly in water to give concentrated sulphuric acid? (***0.40 mark***)

Option	Solution
A	To reduce the hazards of spillage
B	Because the density of the product is too high
C	To minimise transport costs of large volumes
D	Because the last step of the process is too expensive
E	Because the last step of the process is too exothermic
F	An aerosol of the sulphuric acid rapidly fills the room

Answer	Options	
I	C	**0.2 Mark**
II	F	**0.2 mark**

2.2. Match the role that sulphuric acid plays in manufacturing with each of the following industrial activities as shown below:

(i) Electroplating of iron and steel (***0.25mark***)
(ii) Fertilizer industry (***0.25mark***)
(iii) Manufacture of detergents (***0.25mark***)
(iv) Automotive industry (***0.25mark***)

Option	Industrial Role
A	Sulphuric acid dissolves the iron and steel
B	Dissolution of phosphate rocks
C	Manufacture of lead acid accumulators
D	Cleaning of metal surfaces by dissolution of oxide layers
E	Functionalization of compounds with SO groups

Industrial activity	Option	
i	D	**0.25 mark**
ii	B	**0.25 mark**
iii	E	**0.25 mark**
iv	C	**0.25 mark**

2.3. Write balanced equations for the four major reactions in the Contact process. (***2.0marks***)

Equation 1	$S + O_2 \longrightarrow SO_2$	**0.5 mark**

Equation 2	$2SO_2 + O_2 \rightleftharpoons 2SO_3$	**0.5 mark**
Equation 3	$SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$	**0.5 mark**
Equation 4	$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$	**0.5 mark**

2.4. Choose one option from A-C why vanadium (V) oxide is suitable for use as a catalyst in the Contact process (***0.25mark***)

A. Vanadium (V) oxide removes electron from SO_2 and is re-oxidised by oxygen

B. Vanadium (V) oxide supplies electrons to SO_2 and is in turn reduced to vanadium (III) ions

C. Vanadium (V) oxide reacts with oxygen to give a complex which is regeneratable

Correct ans: A (0.25 mark)

2.5. Use appropriate ionic equations to show the reduction and re-oxidation of the vanadium ions (***1.0mark***)

Equation 1	$V^{5+} + 2e^- \longrightarrow V^{3+}$ OR $4V^{5+} + 2SO_2 + 2O^{2-} \longrightarrow 2SO_3 + 4V^{4+}$	**0.5 mark**
Equation 2	$2V^{4+} + \frac{1}{2}O_2 \longrightarrow 2V^{5+} + O^{2-}$ OR $4V^{3+} + O_2 \longrightarrow 4V^{5+} + 2O^{2-}$ OR $V^{3+} \longrightarrow V^{5+} + 2e^-$	**0.5 mark**

2.6. If the Contact process is 80% efficient, calculate the weight of 98% sulfuric acid produced from 100 kg of pure sulphur. Assume 100% conversion of sulphur to sulphur (IV) oxide. (S = 32.0, H = 1.0, O = 16.0 and density of 98% sulfuric acid is 1.98g/cm^3).
(1.0mark)

$S + O_2 \longrightarrow SO_2$ **(0.1 mark)**

32 g $\equiv$ 64 g **(0.1 mark)**

$100000g \ \ will\ give \ \ \frac{64}{32} \times \frac{100000}{1} = 200{,}000\,g \ \ SO_2$ **(0.1 mark)**

In the contact process:

$2SO_2 + O_2 \longrightarrow 2SO_3$ **(0.1 mark)**

128 g $\equiv$ 160 g **(0.1 mark)**

$200{,}000 = \frac{160}{128} \times 200{,}000 = 250{,}000\,g \ \ SO_3$ **(0.1 mark)**

At 80% efficiency:

(250,000 g SO_3 x 80)/ 100 = 200, 000 g SO_3

$SO_3 + H_2O \longrightarrow H_2SO_4$ **(0.1 mark)**

80 g = 98 g **(0.1 mark)**

$200{,}000 \;=\; \frac{98}{80} \times 200{,}000 \;=\; 245{,}000 g\ H_2SO_4\ for 100\%\ pure$ **(0.1 mark)**

Let the weight of 100% pure sulfuric acid = W_1 = 245, 000 g and weight of 98% sulfuric acid = W_2

Therefore 100% x 245,000 g = W_2 x 98%

Hence W_2 = (100 x 245, 000g)/ 98 = 250,000g of 98% H_2SO_4 **(0.1 mark)**

2.7. Write a balanced equation for the reaction of excess sodium chloride and concentrated sulfuric acid. **(*0.5mark*)**

Answer:

$2NaCl + H_2SO_4 \longrightarrow 2HCl + Na_2SO_4$ **(0.5 mark)**

2.8. Write a balanced equation representing the dehydration of sucrose by concentrated sulphuric acid. The formula for sucrose is $C_{12}H_{22}O_{11}$ **(*0.5mark*)**

$$C_{12}H_{22}O_{11} \xrightarrow{H_2SO_4} 12\,C + 11H_2O$$

OR

$$C_{12}H_{22}O_{11} + 11H_2SO_4 \rightarrow 12\,C + 11H_2SO_4.\,H_2O$$

2.9. Sulfuric acid is a diprotic acid. Write equations to show its ionization in water **(*0.5mark*)**

Equation 1	$H_2SO_4 \longrightarrow HSO_4^- + H^+$ **OR** $H_2SO_4 + H_2O \longrightarrow HSO_4^- + H_3O^+$	**(0.25 mark)**
Equation 2	$HSO_4^- \longrightarrow SO_4^{2-} + H^+$ **OR** $HSO_4^- + H_2O \longrightarrow SO_4^{2-} + H_3O^+$	**(0.25 mark)**

2.10. Determine the volume of gas produced in the first stage of the Contact process when 200 g of sulphur is converted to sulphur (IV) oxide at 300°C and 1 atmosphere pressure. Assume the conversion of sulphur to sulphur (IV) oxide is 100%).

R = 0.082 l-atm mol^{-1} K^{-1} **(*1.25 marks*)**

$$V = \frac{nRT}{P}$$ **(0.25 mark)**

S ⟶ SO_2

32 g = 64g **(0.25 mark)**

$$200g = \frac{64}{32} x\ 200 = 400g$$ **(0.25 mark)**

$$n = \frac{400}{64} = 6.2mol$$ **(0.25 mark)**

$$V = \frac{nRT}{P} \equiv \frac{6.255 \times 0.082 \times 573}{1} = 293.66l$$ **(0.25 mark)**

2.11. What volume of 0.20 mol dm^{-3} sulphuric acid is required to neutralise completely 25 cm^3 of 16.0g of sodium hydroxide dissolved in 0.25 dm^3 of water? (Na = 23.0, O = 16.0, H = 1.0, S – 32.0) ***(1.0 mark)***

$$Molarity\ of\ NaOH = \frac{16}{40} \times \frac{1000}{250} = 1.6M$$ **(0.25 mark)**

$$\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$$ **(0.25 mark)**

$$\frac{0.2 \times V_a}{1.6 \times 25} = \frac{1}{2}$$ **(0.25 mark)**

$$V_a = \frac{1.6 \times 25}{0.2 \times 2} = 100cm^3$$ **(0.25 mark)**

***Note: A bonus mark of 1 for attempting question 2.11 (different versions of question was given).**

2.12. From the list supplied below, select three (3) fuels that will give the most acid rain.
(1 Firewood (b) petroleum (c) coal, (d) biodiesel (e) bioethanol, (f) natural gas

(0.60 marks)

Selection	Fuel	
i	b	**0.2 mark**
ii	c	**0.2 mark**
iii	f	**0.2 mark**

3.1 **(0.5 Mark)**

No. caught and marked in first sample (M)	Total caught in second sample (C)	Number marked in second sample (R)
109	177	**177 – 120 =57**

N=M(C)(R)

= (109)(177)/57 **(0.5 mark)**

= 19293/57

= 338.47 Catfish /338 catfish/ 339 catfish **(0.5 mark).**

3.2 Population size: N=M(C)(R) **(1.0 Mark)**

3.2.1. (0.5 Total Mark)

	Reason:	True	False
1.	The marking procedure makes the animal more conspicuous to predators.	**X 0.125 mark**	
2.	There is an increase in the number of predators.		**X 0.125 mark**
3.	The marking process is toxic/harmful to the animal.	**X 0.125 mark**	
4.	A toxic chemical is introduced into the environment.		**X 0.125 mark**

3.3.1. Mean number of earthworm cast per quadrat. **(1.0 Total mark)**

Number of worm cast (x)	Number of quadrats (f)	fx
0	17	0
1	20	20
2	28	56
3	18	54
4	8	32
5	8	40
6	0	0
7	0	0
8	1	8
Total	100	210

Mean (X)= i=1nfxf

= $\frac{210}{100}$ **(0.5 mark)**

= **2.1(0.5 mark)**

3.3.2. Calculate the variance (S2) and determine the variance to mean ratio **(1.0 Total mark)**

Number of worm cast (x)	Number of quadrats (f)	x-x	$(x-x)^2$	$f(x-x)^2$
0	17	-2.1	4.41	74.9
1	20	-1.1	1.21	24.2
2	28	-0.1	0.01	0.28
3	18	0.9	0.81	14.58
4	8	1.9	3.61	28.88
5	8	2.9	8.41	67.25
6	0	3.9	15.21	0
7	0	4.9	24.01	0
8	1	5.9	34.81	34.81
∑	100			244.9

(0.4 mark)

$= \frac{244.9}{100-1}$ **(0.2 mark)**

$= \frac{244.9}{99}$

S^2 = 2.5 **(0.1 mark)**

Variance to mean ratio (S2/x) = 2.5/2.1

= **1.2** **(0.3 mark)**

3.3

3.3.3. From your answer to **3.3.2** above, which of the observations below is correct:

Option	**Variance-to-mean ratio (s^2/x)**	**Conclusion**	**Tick (√) appropriate box below**
I	0.8 – 1.2	The distribution closely follows a random pattern.	√ **(0.5 mark)**
II	>1.2 or <0.8	The distribution does not follow a random pattern.	

3.4.1. Complete the Table below (**1.2 marks**)

Species of earthworm	**No. collected**	**n(n-1)**
Eudriluseugeniae	10	90 (0.2 mark)
Hyperiodrilusafricanus	15	210 (0.2 mark)
Lybodrilusviolaceus	16	240

		(0.2 mark)
Alma millsoni	9	72 (0.2 mark)
Total (N)	50	**i=1n=** 612 **(0.4 mark)**

3.4.2. Determine the diversity (d) of earthworms in the snail farm. **(1.0 Total mark)**

d= N(N-1)i=0nn(ni-1)

$$d = \frac{50\,(50-1)}{10(10-1)+15(15-1)+16(16-1)+9(9-1)}$$ **(0.5 mark)**

$$d = \frac{50(49)}{90 + 210 + 240 + 72}$$ **(0.2 mark)**

$$d = \frac{2450}{612}$$

d = 4.00 **(0.3 mark)**

3.4.3. (Mark X into the boxes) **(0.8 Total marks)**

	True	False
a) plant roots do notabsorb oxygen from the soil because it is transported from the leaves		X (0.2 mark)
b) earthworms themselves use the oxygen from the soil	X (0.2 mark)	
c) bacteria that transform the ammonia produced by animals into nitrate, need the oxygen from the soil	X (0.2 mark)	
d) Oxygen from the soil is necessary for the decomposition of the organic matter		X (0.2 mark)

3.4.4. The earthworm casts consist of compounds containing elements. Plants need elements. Which of the elements contained in the casts, is the most important for the plant to take up using their roots? Choose one of the following elements: O, C, N, H
Answer: **N** (0.5 mark)

3.5.1. Use the data in the table to present this information by drawing a suitable graph. **(1.5 Marks)**

Appropriate graph (each column x 0.125) = 1.0 mark
Correct scale = 0.3 mark
Correct units= 0.2 mark
Total score 1.5 marks.

3.5.2. From the graph which of the observations below is/are the most probable conclusion(s).Tick **(√)** the correct boxes **(0.5 Mark)**

(i) The red colour induced the highest amount of casts produced in the lighted portion, the least amount of casts in the dark portion. √

(ii) Colour of light has no effect on the behavioral responses of worm to light exposure. ☐

(iii) *Hyperiodrilus* sp.could not diffentiate between the different light colours. ☐

(iv) Green colour induced the highest amount of casts produced in the dark portion. ☐