1. Consider the electrolytic cell shown figure 1.
   For this cell answer the following questions.

   a. Write the balanced equation, with states, for the half reaction taking place at the:
   Important to note that water is the strongest oxidant and the strongest reductant.

   Anode ________________________ 2 marks

   $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

   1 ---- mark balanced 1----- mark states

   Cathode ________________________ 2 marks

   $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

   1 ---- mark balanced 1----- mark states

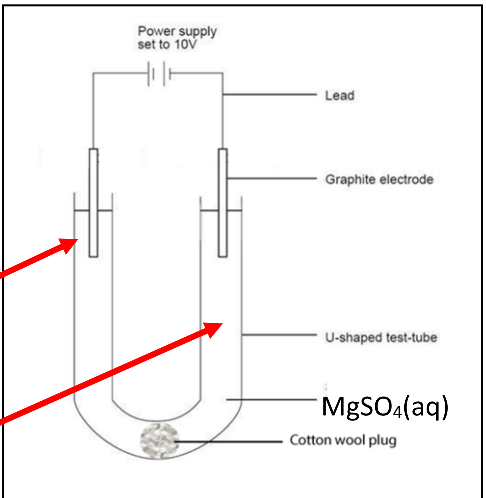


Figure 1

   b. Explain how the pH at the anode will change over time as the cell operates. 2 marks

   $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

   1 ---- mark pH will decrease 1----- mark due to the formation of H^+ ions as shown in the balanced half equation.

   c. A current of 5.50 amps was applied for 1.50 minutes. Calculate the volume, in litres, of gas produced at the cathode at SLC? 4 marks

   $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

   => Q =It => 5.50 X 1.50 X 60 = 495 Coulomb 1 ----- mark

   => n_e = 495/96500 = 5.13 X 10^{-3} mol 1 ----- mark

   => $n_{hydrogen\ gas}$ = 5.13 X 10^{-3} X ½ = 2.56 X 10^{-3} 1 ---- mark

   => 24.8 X 2.56 X 10^{-3} = 0.0636 litres 1 ------ mark

2. Consider the electrochemical cell shown on the right. It is composed of a 1.0 M $ZnSO_4$ electrolyte solution and two carbon electrodes connected to a power source.

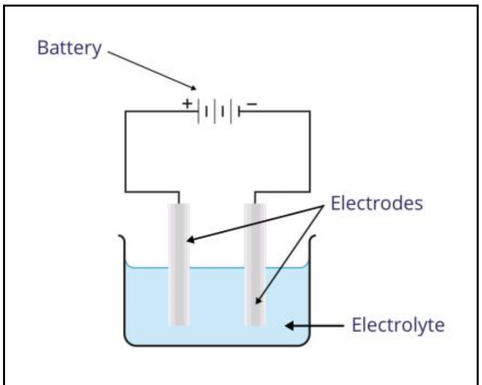


Figure 2

a. Give the half reactions taking place at the:

   i. Anode ________________________ 2 marks

   $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

   1 ---- mark balanced 1----- mark states

   ii. Cathode ________________________ 2 marks

   $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

   1 ---- mark balanced 1----- mark states

b. Which electrode is gaining mass? 1 mark

   Cathode

c. The power source delivers a current at a voltage of 5.00 volts. If electrical energy equivalent to 4000 kJ is delivered what is the mass gain of the electrode specified in b. above? 4 marks

$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

=> $E(j) = VI\,t = VQ$ => $Q = E/V$ 1 ------ mark

=> $Q = 4.00 \times 10^6\ J / 5.00 = 8.00 \times 10^5 C$ 1 ------ mark

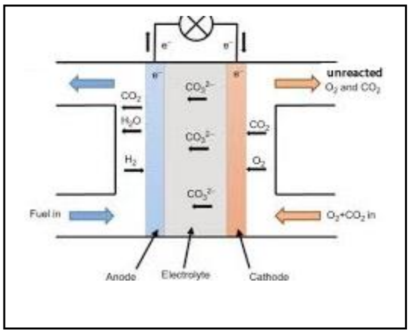
=> n_e = $8.00 \times 10^5 / 96500 = 8.30$ mol 1 ------ mark

=> $n_{Zn} = 8.30 \times ½ = 4.15$ => mass of Zn = 65.4 X 4.15 = 271 grams 1------- mark

3. Consider a molten carbonate fuel cell with molten Na_2CO_3 electrolyte operating at 800°C.

a. In the space provided below, draw a molten carbonate (Na_2CO_3) fuel cell burning methane gas in atmospheric oxygen. 4 marks

- label the anode and cathode. *1 ----- mark*
- identify the ions moving through the electrolyte and clearly indicate their direction *1 ----- mark*
- give the half equations, states not necessary, for the reactions taking place at the:



Anode ___________________________________

$CH_4 + 4CO_3^{2-} \rightarrow 5CO_2 + 2H_2O + 8e^-$ 1 ----- mark

Cathode ___________________________________

$2CO_2 + O_2 + 4e^- \rightarrow 2CO_3^{2-}$ 1 ----- mark

b. Give the balanced equation, states included, for the overall reaction taking place in the fuel cell. 2 marks

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ 1 ------ mark for states, water at 800°C is a gas 1 ------- mark balanced with proper formulae

c. A great deal of heat is produced during the operation of the fuel. Give one use for the hot waste gases, that would maximise electrical energy output. 2 marks

Any viable suggestion.

1 ---------- mark for a viable suggestion

1 ---------- marks for an explanation of the viability.

Eg hot waste gases can be reused to drive an electrical generator. 1------- mark.

This would increase the capacity of the system to produce extra electrical energy via a generator. 1 ------- mark

d. The exhaust gases are finally vented out at of the fuel cell at SLC. Calculate the net volume, in litres, of CO_2 gas added to the atmosphere over a 24.00 hour period if the cell produces a constant current of 5.90 amps. Give your answer to the right number of significant figures. 5 marks

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
=> Q = It => 5.90 X 24.0 X 60 X 60 = 509760 Coulombs — *1 ------ mark*
=> n_e = 509760 /96500 = 5.283 — *1 ------ mark*
=> $CH_4 + 4CO_3^{2-} \rightarrow 5CO_2 + 2H_2O + 8e^-$
=> mol of methane consumed = 5.283 / 8 = 0.660 — *1 ----- mark*
=> according to the overall equation, the amount of net CO_2 produced should also be 0.660 mol — *1 ------- mark*
=> volume at SLC = 0.660 X 24.8 = 16.4 L (3 sig figs) — *1 ------- mark*

4. The predominant constituent of Jatropha curcas oil is a fatty acid called oleic acid. The composition of the plant oil is given in table 1 below.

Oil	% composition by mass	Heat of combustion (kJ/g)
Oleic acid	50	39.4
Linoleic acid	40	37.1
Palmitic acid	10	39.0

Table 1

Figure 3
Jatropha curcas

Jatropha curcas is known for its ability to grow in low-quality or marginal soils, which makes it suitable for cultivation in areas where other crops may struggle. It is often referred to as a "wasteland plant" because it can thrive in soils that are nutrient-poor, sandy, rocky, or otherwise unsuitable for many other agricultural crops.

a. Calculate the amount of energy given by 0.1000 kg of pure Jatropha curcas oil. 2 marks

energy from Oleic acid = 39.4 X 50g = 1970 kJ
energy from Linoleic acid = 37.1 X 40 = 1484 kJ
energy from Palmitic acid = 39.0 X 10 = 390 k — *1 ----- mark for correct calulations*
Total = 3.8×10^4 kJ (2 sig figs) — *1 ---- mark for answer and sig figs.*

b. Petrodiesel, produced from crude oil is mainly characterised as $C_{12}H_{24}$. Compare biodiesel produced from Jatopha curcas oil with petrodiesel by completing the table below. Use your knowledge of chemistry to give a detailed explanation.

Factor	Biodiesel	Petrodiesel
Energy density (kJ/g)	*38kJ/g 1 ------mark* *Lower than petrodiesel as biodiesel, being an ester is already partly oxidised. Students could also refer to the petrodiesel having higher energy density for the exact opposite reason.* *1 ---- mark*	*45 kJ/g as per data booklet 1-----mark*
Usage in low temperature climates	*Limited use in low temperature climate due to high melting point (MP)* *1 ----- mark for referring to suitability and MP.* *Relatively strong intermolecular bonding composed of: 1 ---- mark for mentioning stronger intermolecular bonds in the biodiesel.* *- dipole dipole due to ester bond* *1 ---- mark for reference to ester bond* *- dispersion forces*	*Well suited to low temperature climates due to low melting point.* *Relatively weak intermolecular bonding composed of dispersion forces.* ***For the three marks to be awarded students needed to correctly compare both fuels. Not sufficient to say "Biodiesel has strong intermolecular bonding without mentioning how the intermolecular bonding in petrodiesel"***

c. Compare and contrast the two biofuels, namely bioethanol and biodiesel by answering the questions in the table below.

Question	Answer	Justification
Is bioethanol sustainable and renewable?	*No* *as long as this can be justified in the next column* *1 ---- mark*	*Bioethanol is renewable as it can be produced at a rapid rate so it can not be depleted 1 ------- mark* *It is not sustainable as it competes with food crops for available land. 1 ------- mark*
Is biodiesel made from Jatopha curcas oil sustainable and renewable?	*Yes* *as long as this can be justified in the next column* *1 ---- mark*	*Biodiesel is renewable as it can be produced at a rapid rate so it can not be depleted 1 ------- mark* *It is also sustainable as it does not compete with food crops for available land as it is grown on waste land.* *1 ------- mark*

d. Given that the average molecule in petrodiesel has the molecular formula $C_{12}H_{24}$:

i. give the balanced equation, states included, for the complete combustion of petrodiesel at SLC.

$C_{12}H_{24}(l) + 18O_2(g) \rightarrow 12CO_2(g) + 12H_2O(l)$

1 ------- mark for balanced and accurate formulae

1 ------- mark for correct states (water (l) and petrodiesel (l)

ii. calculate the volume, in litres, of gas released from the complete combustion that occurs when 480.00 litres of oxygen completely react in excess fuel, at SLC. Give your answer to the right number of significant figures.

=> CO_2 is the only gas produced in the ratio of 12/18 with oxygen gas consumed

1 ----- mark if the correct ratio is used in the calculations

=> Volume of CO_2 = 480 X 2/3 = 320.00 litres (5 sig figs)   1 ----- mark for accurate answer to 5 sig figs.

Students should be aware that at constant temperature and pressure volumes of gases can be used similar to mol in stoichiometric volume to volume calculations.

e. The simplified reaction pathway shown below in fig. 4 is of the transesterification process to form biodiesel.

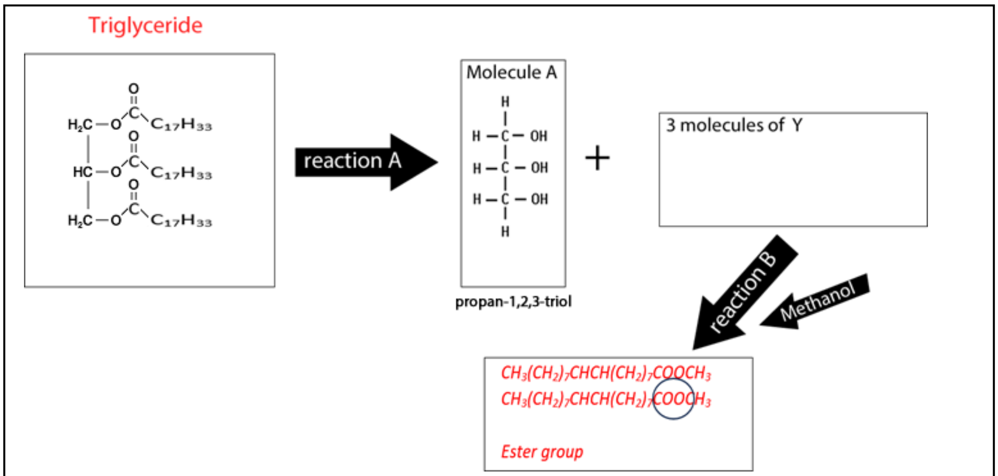


Figure 4

Transesterification

i. Draw the structural formula, in the box provided in fig 4, of one triglyceride molecule formed from oleic acid. Use the molecular formula of oleic acid ($C_{17}H_{33}$-COOH) in your representation of the triglyceride. 2 marks

ii. What class of reaction is represented by reaction "A"?

_______*Hydrolysis*_______ 1 mark

iii. Apart from the triglyceride, what other molecule is needed as a reactant for reaction "A"? _________*H_2O*_______________ 1 mark

iv. Draw the structural formula of molecule "A" in the box provided and give its IUPAC name. 2 marks

v. To which class of fatty acids do the molecules of "Y" belong to?

____________*monounsaturated fatty acids* ____ 1 mark

vi. To what general class of reaction does reaction "B" belong to?

_______*Condensation*_________ 1 mark

vii. Give the ***condensed*** formula for the biodiesel formed as a product of reaction "B" in the box provided in fig 4, circle and name the functional group within the biodiesel molecule. 3 marks

$CH_3(CH_2)_7CHCH(CH_2)_7COOCH_3$ *1 ------ mark The condensed formula could have largely been obtained from the data booklet. It pays for students to be familiar with the contents of the data booklets and how to use it.*

$CH_3(CH_2)_7CHCH(CH_2)_7COOCH_3$ *1 ------ mark if both Cs are included in the circle*

Ester group *1 ------ mark*

viii. With reference to functional groups and intermolecular bonds discuss why molecule "Y" is not used directly as a fuel but rather is converted into biodiesel by reaction with methanol. 3 marks

Molecule "Y" is a fatty acid whilst the biodiesel in composed of methyl esters. The fatty acids have a higher melting point and are more viscous than the biodiesel causing possible blockage in the fuel lines.
1 ------ mark
Molecules of "Y" have carboxyl functional groups and hence can undergo hydrogen bonding as well dispersion forces which causes a stronger intermolecular force of attraction to take place. 1 ----- mark
The biodiesel, with ester groups has dipole-dipole as well as dispersion forces acting and the intermolecular forces of attraction are weaker than those present in the fatty acid. 1 ----- mark

f. In an attempt to calculate the heat of combustion, in kJ/g, the setup shown in fig.5 was used. The entry, shown below, was found in a student's log book.

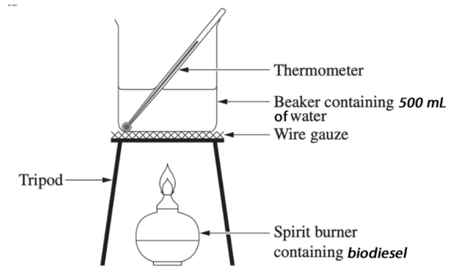


Figure 5

"Mass of spirit burner and fuel before combustion -------------- 234.00 grams
Mass of spirit burner and fuel after combustion ---------- 231.69 grams
Temperature of water before combustion ------- 25.0 °C
Temperature of water after combustion ------- 69.2 °C

i. Calculate the amount of energy, in kJ, released by the burning of the fuel. Give your answer to the right number of significant figures. 3 marks
E(J) = 4.18 X 500 mL X 1.0 g/mL X 44.2 °C = 92 kJ
1 ---- mark accurately converting volume to mass
1 ---- mark correct value in kJ. Unit not required since the units are specified in the question.
1 ---- mark realising that the density of water int eh data booklet is given to 2 sig figs hence the answer must be given to 2 sig figs.

ii. What is assumed when calculating the answer to question i. above? 1 mark

All energy released by the fuel is absorbed by the water. 1 ----- mark

iii. Calculate the energy density of the fuel in kJ/g. 1 mark

92 / (234.00 – 231.69) = 4.0 X 10^1 kJ/g

iv. The published literature value for the energy density of the fuel is 34.2 kJ/g. Discuss how this compares with the student's experimental result and suggest two possible errors that may have contributed to the discrepancy. 3 marks

The experimental value is higher than the literature value. 1 ---- mark
possible error
Any valid error that leads to the experimental value being higher than the true value.

- *Less than 500 mL of water was used hence the temperature change was abnormally high. 1 ---- mark*
- *Failure to stir the water hence the water under or near the thermometer was hotter than the rest of the body of water in the beaker. 1 ---- mark*

5. Consider the galvanic cell shown on the right in fig. 6. It is allowed to discharge at standard conditions.

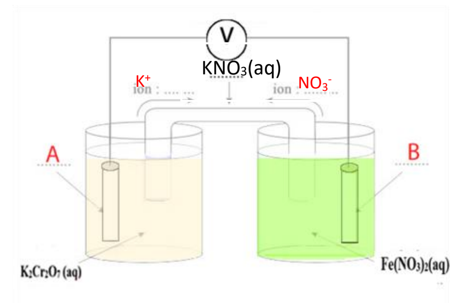


Figure 6

a. What is the theoretical voltage registered by the voltmeter. 1 mark

1.36 - 0.77 = 0.59 V 1 ---- mark

b. Give a possible material that can be used to form both electrodes "A" and "B" 1 mark

_____________*Any conducting, inert material eg Pt(s) or C(s)*_________________________

c. Describe how the function of the cell in fig 6 would change if electrode "A" is replaced with an iron electrode. Justify your answer with reference to the electrochemical series given in the data booklet. 2 marks
Heat is the primary energy released not electrical energy 1 ---- mark
As the strongest oxidant ($Cr_2O_7^{2-}$) and the strongest reductant Fe(s) are in direct contact with each other 1 ---- mark

d. State one limitation of the electrochemical series provided in your data book. 1 mark
The rate of the reaction is not taken into account. 1 ---- mark

e. Describe the colour change that takes place in the half cell with electrode "A", during discharge. 1 mark

From orange to green 1 ---- mark (for the one mark the initial and final colour must be specified)

f. In the space provided in fig. 6 indicate the ion and its state, travelling through the salt bridge in the direction indicated by the arrows. 2 marks
1 ----- mark for correct ion
1 ----- mark (aq) state

g. Describe how the pH in the cell with electrode "A" changes over time during discharge and give an explanation using a balanced half equation. 2 marks

PH will increase *1----- mark*

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

as the $H^+(aq)$ ions get used up in the half cell reaction shown above. *1 ---- mark*

h. The cell is now connected to a power source in order to recharge, as shown in fig 7.

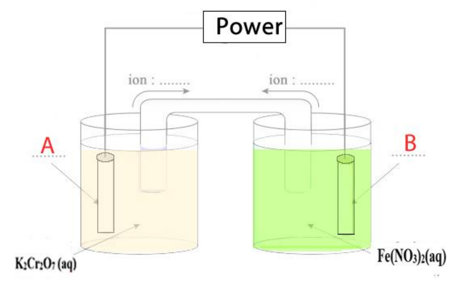


Figure 7

i. Give the polarity of electrode "B" and describe how its polarity changes from discharge to recharge. 7 marks

	Recharge	Discharge
Polarity of electrode "A"	*positive*	*positive*
Polarity of electrode "B"	*negative*	*negative*
Oxidation takes place at which electrode	*A*	*B*
Reduction takes place at which electrode	*B*	*A*
Energy transformation	*Chemical → electrical*	*Electrical → chemical*
Voltage produced	*0.59 V*	*N/A*
Voltage applied	*N/A*	*> 0.59 V*
Reaction taking place at electrode "B"	*$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$*	*$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$*

ii. With reference to the electrochemical series, give an explanation as to why recharging this particular galvanic cell might be very difficult. 2 marks

According to the E° tables $Cr^{3+}(aq)$ is a weaker reductant than $H_2O(l)$. *1 ---- mark*

The oxidation half reaction taking place will be $2H_2O(l) \rightarrow O_2(g) + 4H^+ + 4e^-$ instead of the oxidation reaction $2Cr^{3+}(aq) + 7H_2O(l) \rightarrow Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$ *1 ---- mark*

6. Calcium carbonate (limestone) powder was added to a 250 mL beaker and then reacted with 100 mL of a 0.1 M HCl. Carbon dioxide gas and liquid water were two of the three products formed from this reaction.

   a. Using your knowledge of acid reactions covered previously (year 11), write the balanced chemical equation for the reaction taking place at SLC. States included 2 marks

____

   b. The volume of gas produced over time was graphed and shown in fig 8. The graph shows the reaction taking place at 10 °C without a catalyst.

   i. Draw a clearly labelled graph of volume of gas versus time for exactly the same reaction with the same amount of reactants but at 30 °C on the set of axes shown in fig 8. 1 mark

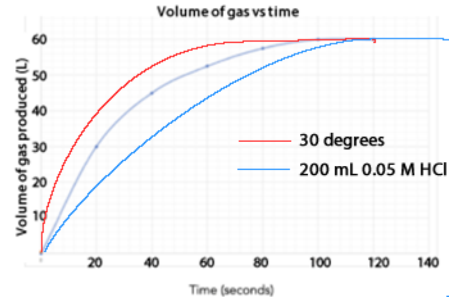


Figure 8

   ii. On the same set of axes, shown in fig. 8, draw a clearly labelled graph of volume of gas versus time for the same reaction but with 200 mL of 0.05 M HCl. Justify the shape of the curve using collision theory. 3 marks

   1 ---- mark for correct line

   Dilute solution provides less opportunity for collisions amongst reactant particles

   1--- mark --- must mention dilute or give some indication that reactant particles are further apart.

   And hence less frequent fruitful collisions

   1 ---- mark ---- must mention successful or fruitful collisions.

   c. Shown on the right is the Maxwell-Boltzmann distribution curve for particles at 10 °C.

   i. Draw the distribution curve for the same amount of particles at 30 °C. 2 marks

   1---- mark for correct shape

   1 --- mark for same area under the curve

   ii. Use this distribution curve to justify the shape of the curve drawn as an answer to question b part i. above. 2 marks

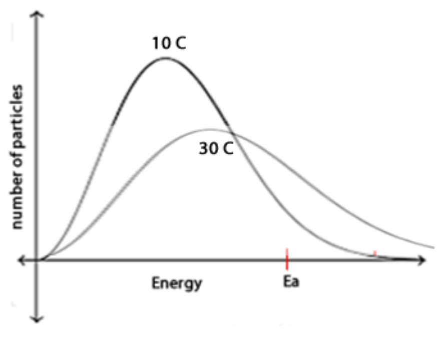


Figure 9

   Since the graph drawn as a response to question b part i. above should show a steeper curve indicating a faster rate of reaction the explanation given to this question must include.

   A greater proportion of particles have kinetic energy equal to or greater than the activation energy at 30 °C as compared to 10 °C *1---- mark*

   Therefore a greater proportion of collisions will be more fruitful *1 ---- mark*

d. Use the maxwell-Boltzmann distribution curve shown in fig 10 to explain why a catalyst increases the rate of a reaction. 4 marks

A catalyst decreases the activation energy of a reaction. 1 ---- mark

By decreasing the activation energy it increases the proportion of particles that can undergo fruitful collisions.

1 ---- mark for increasing the proportion of particles with equal to or greater than the activation energy required to react.

1 ----- mark for mentioning fruitful or successful collision.

1 ---- mark for accurately shading the area under the graph representing the number of particles with equal to or greater than the activation energy.

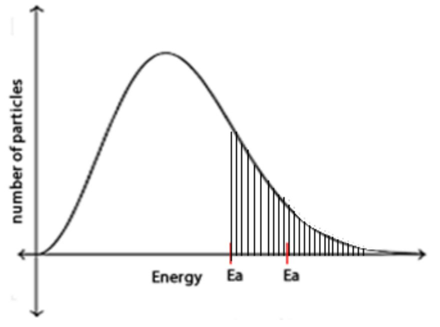


Figure 10

e. For each of the following statement relating to the reaction above state if they are true or false and give a brief explanation as to why.

i. If a catalyst is used the reaction rate will increase due to the number of collisions between the reactants increasing. 2 marks

False 1 ---- mark

A catalyst does not increase the number of collisions. It increases the proportion of particles with the minimum energy required to initiate a reaction. 1 --- mark

ii. As the temperature of the acid solution is increased so does the rate of the reaction because all reactant particles have greater kinetic energy and collide more frequently. 2 marks

False 1 ---- mark

Not all reactants particles have a higher kinetic energy, the average kinetic energy is greater but not for all particles. 1 ---- mark

iii. When a catalyst is used it reduces the activation energy of the forward and backward reactions by the same proportion.

False 1 ---- mark

Be careful of the wording here.

The activation energy is reduced by the same amount not "by the same proportion" 1 ---- mark