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VCE Chemistry ¾

AOS 1 (Fuels & Energy) [1.0]

SAC 2 Solutions

50 Marks. 5 Minutes Reading. 60 Minutes Writing.

Section A: Multiple Choice Questions (5 Marks)

Question 1 (1 mark)

Methane gas can be produced through the formation of biogases as well as from natural gas deposits. Methane gas is a ?

A. Renewable fuel as it is produced by natural processes over a relatively short amount of time.

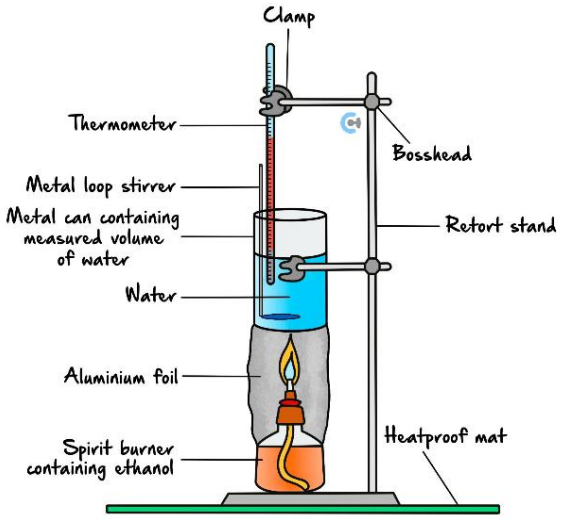
B. Non-renewable fuel as it requires machinary that releases additional carbon dioxide into the atmosphere.

C. Renewable and non-renewable due to varying mechanisms of sourcing.

D. Renewable and non-renewable as the processing of methane can release carbon emissions.

Question 2 (1 mark)

The molar heat of combustion of a fuel is to be determined through an experiment. The set up used in experiment is shown below.



Which of the following incorrectly outlines a feature of the set up and its intended purpose.

A. Aluminium foil prevents heat loss from occuring between the spirit burner and the beaker.

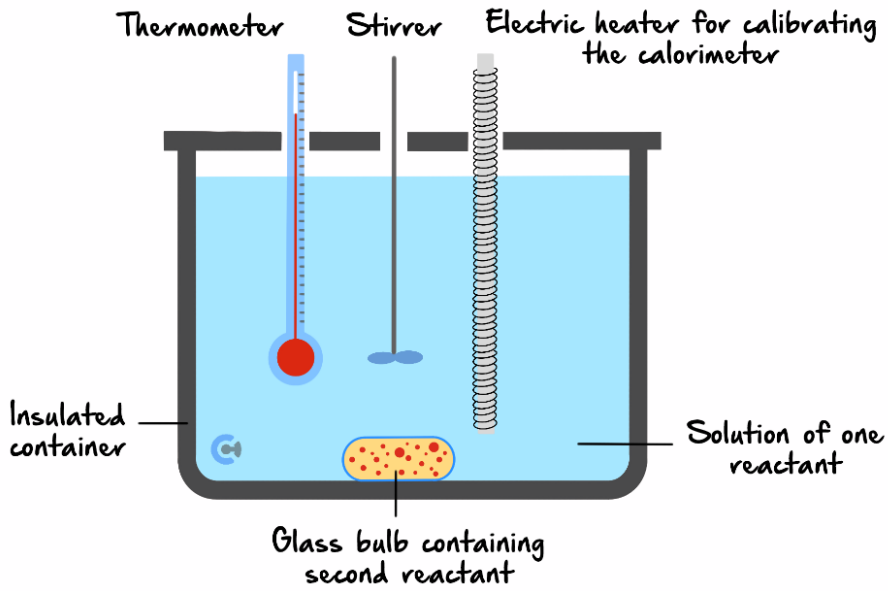
B. Heat proof mat absorbs thermal energy ensuring less heat loss occurs.

C. Metal loop stirrer ensures heat is evenly distributed throughout the water.

D. The base of the beaker has a large surface area in order to maximise heat transfer from spirit burner to the water.

Question 3 (1 mark)

Solution calorimeters such as the one shown in the diagram below, rely on a glass bulb to store reactants.



Which of the following correctly outlines the main purpose of the glass bulb?

A. Prevent heat from escaping the calorimeter.

B. Ensure reactants are complely reacted.

C. Provide catalysts for reactions that are embedded in the glass bulb.

D. Prevent reactions from pre-maturely starting.

Question 4 (1 mark)

Decane ($C_{10}H_{22}$) has a molar heat of combustion of -6.78 MJ mol^{-1}. A 1 mol sample of decane is combusted within a bomb calorimeter and the energy released is recorded to be 6.67 MJ of energy.

Decanol ($C_{10}H_{21}OH$) is placed in the same calorimeter and is combusted.

The expected amount of energy (E) released by the decanol is?

A. $E > 6.78\ MJ$

B. $6.67\ MJ < E < 6.78\ MJ$

C. $E < 6.77\ MJ$

D. $6.00\ MJ < E < 6.67\ MJ$

Question 5 (1 mark)

For an unknown fuel, when it undergoes a reaction it is known that there is a decrease in the enthalpy of the products relative to the reactants.

For this particular reaction of this fuel,

A. the activation energy of the reaction is less than the change in enthalpy of the reaction.

B. there is a decrease in the surrounding temperature.

C. the enthalpy change of the reverse reaction is negative.

D. the products have stronger chemical bonds than the reactants.

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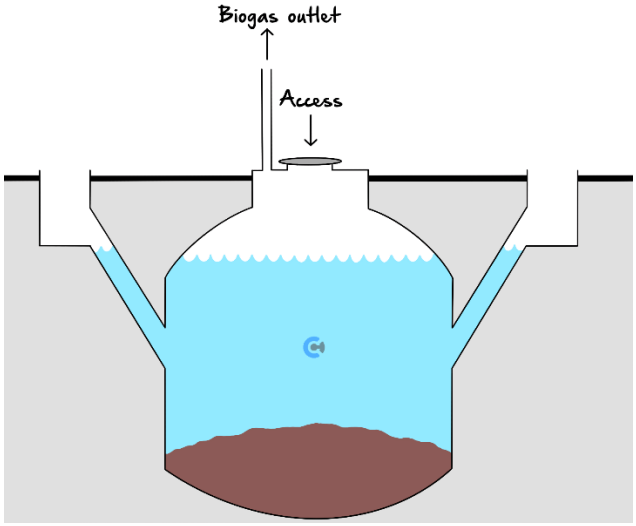
Section B: Short Answer Questions (45 Marks)

Question 6 (8 marks)

For a summer project, Sam and Qing have built a large digester that is able to extract biogas from organic matter incredibly efficiently. A diagram of their digester is shown below.



a. Describe the process in which biogases are produced. (1 mark)

Anaerobic breakdown of organic matter by bacteria.

Additionally, they have been exploring the production of hydrogen gas (H_2) through hydrolysis reactions. An example of a hydrolysis reaction is shown below:

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

b. Outline a potential danger in the production of hydrogen gas. (1 mark)

Hydrogen is extremely flammable, therefore all ignition sources should be kept away from hydrogen gas.

c. Given that 20.0 L of water is reacted at SLC, calculate the volume of hydrogen gas that would be produced. (2 marks)

$$m(H_2O) = 20000\ mL * 0.997 g/mL = 19940\ g$$
$$n(H_2O) = \frac{19940 g}{18.0\ g/mol} = 1107.78\ mol$$

$n(H_2) = n(H_2O) = 1107.78$ mol

$V(H_2) = n * V_m = 1107.78 * 24.8$

$= 27472.89$ L

$= 2.74 * 10^4$ L

d.

i. 10.0 L of both hydrogen gas and methane undergoes complete combustion. Calculate the amount of energy either fuel produces. (2 marks)

$$n(H_2) = \frac{V}{V_m} = \frac{10.0L}{24.8} = 0.403\ mol$$
$$n(CH_4) = \frac{V}{V_m} = \frac{10.0L}{24.8} = 0.403\ mol$$
$$q(H_2) = n \times \Delta H = 0.403\ mol \times 286\ kJ/mol = 115.3\ kJ = 115\ kJ$$
$$q(CH_4) = n \times \Delta H = 0.403 \times 890 = 358.57\ kJ = 359\ kJ$$

ii. When Sam and Qing combust their own 10.0 L samples of hydrogen gas and biogas, they find that the hydrogen gas releases more energy. Describe a potential explanation for this observation. (2 marks)

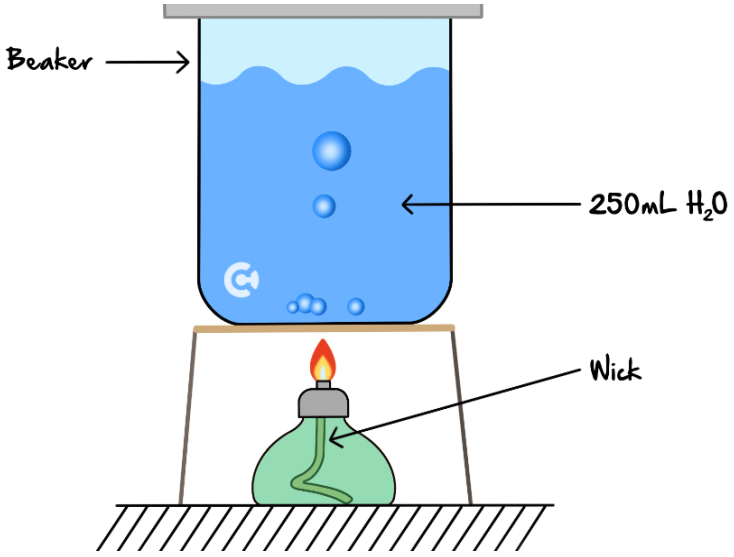
Biogas is not pure methane. It is a mixture of carbon dioxide and methane. The biogas sample they had would have been very low in methane content and thus would release less energy than hydrogen gas which is always pure.

Question 7 (9 marks)

A group of Contour students are exploring different properties of fuels.

They have two unknown fuels. Fuel A and Fuel B, that are of identical carbon chain length.

Fuel A is placed in a spirit burner initially weighing 12.50 g. It is the allowed to completely combust whereby the spirit burners final weight was 11.79 g. The spirit burner heated up a beaker containing 250 mL of water initially at SLC. The final temperature of the water increased by 9.50 ℃. A diagram of the set up is shown below.



a. Calculate the heat of combustion of the fuel in $kJ\ g^{-1}$. (2 marks)

$$m(fuel) = 12.50g - 11.79g = 0.71g$$
$$q = mc\Delta T = 250mL \times 0.9997 \times 4.18 \times (9.5) = 9878J = 9.90\ kJ$$
$$\Delta n = \frac{q}{m} = \frac{9.90kJ}{0.71g} = 13.9\ kJ/g$$

The spirit burner was emptied and Fuel B was immediately added to the spirit burner and combusted. The following data was obtained:

Initial mass of spirit burner – 12.50 g
Final mass of spirit burner – 11.79 g
Initla temperature of water – 42.8 ℃
Final temperature of water – 50.1 ℃

It was noted in the observations that there was a gust of wind in the combustion Fuel B, that resulted in the set up being 90 % efficient.

b. Calculate the heat of combustion of the fuel in $kJ\ g^{-1}$. (2 marks)

$$m(fuel) = 12.50 - 11.79 = 0.71g$$
$$q = mc\Delta T = 250mL \times 0.997 \times 4.18 \times (50.1 - 92.8)$$
$$= 7606J = 7.606\ kJ$$
$$\%\ eff\ =\ 90\%$$
$$\therefore true\ value = \frac{7.606kJ}{0.9} = 8.451kJ$$
$$\Delta H = \frac{q}{m} = \frac{8.451\ kJ}{0.71g} = 11.90\ kJ/g = 11.9\ kJ/g$$

c. Using your response from **part b.,** suggest an error in the current method that may lead to inaccuracies. (1 mark)

The water was now allowed to cool back to the same initla temperature of Fuel A. At higher temperatures the specific heat capacity of water is different and thus the change in temperature will be different.

d. Although both fuels are of similar carbon chain length, the amount of energy they release differs greatly. Explain a potential cause for the large difference in energy contents between the fuels. (2 marks)

Both Fuel A and Fuel B are of same carbon chain length and hence will have similar amount of bonds that can be broken for energy. However, Fuel B is significantly lower in energy content. This is due to Fuel B likely being partially oxidised, whereas Fuel A is not. Thus Fuel B is unable to release as much energy.

e. It is known that one of the fuels can be produced in a renewable manner. State and explain which fuel this is and write the chemical equation for the production of it. (2 marks)

Fuel B is partially oxidised. Therefore it is likely to be ethanol. Ethanol can be produced in a renewable manner through the fermentation of glucose in the chemical. equation: $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Question 8 (9 marks)

As energy demands increase the infrastructure surrounding the production of renewable energy is rapidly improving. A large sector that is seeing this rapid development is the production of bioethanol.

a. Explain how bioethanol is considered a renewable resource. (2 marks)

Bioethanol is able to be produced by the anaerobic fermentation of glucose. This process is driven by natural processes over a relatively short time period (meaning bioethanol feedstocks can be replenished faster than they are consumed) and thus makes bioethanol renewable.

b. A sample of 30.0 kg of glucose has fermented into bioethanol, determine the minimium volume in kL of the the beaker fermentation takes place in given that bioethanol has a density of 0.89 $g\ mL^{-1}$. (3 marks)

$n(C_6H_{12}O_6) = \frac{m}{MR} = \frac{30000g}{180g/mol} = 166.67mol$

$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$

$n(C_2H_5OH) = n(C_6H_{12}O_6) \times \frac{2}{1} = 333.33mol$

$n(CO_2) = n(C_6H_{12}O_6) \times \frac{2}{1} = 333.33mol$

$V(CO_2) = n \times V_m = 333.33 \times 24.8 = 8266.66L$

$d = \frac{m}{V}, V = \frac{m}{d}$

$m(C_2H_5OH) = n \times MR = 333.33mol \times 46g/mol = 15333.18g$

$V(C_2H_5OH) = \frac{15333.18g}{0.89g/mL} = 17228.29L$

$total\ V = 8266.66 + 17228.29 = 25494.95L$

$= 26\ kL$

c. Given a sample of bioethanol and a sample of ethanol weighing the same amount was combusted, explain which would release a greater quantity of energy.(2 marks)

Both would produce the same amount of energy. Fundamentally bioethanol and ethanol are chemically the same.

d. Bioethanol is often added to octane to produce E10 which is a fuel commonly used in modern cars. Provide **one** advantage and **one** disadvantage to adding bioethanol to octane. (2 marks)

Advantages:
- Cheaper to produce bioethanol.
- Bioethanol can be produced renewably.
- Less carbon emissions due to bioethanol containing less carbon.

Disadvantages:
- Lower energy content.
- Large scale production of bioethanol requires lots of land.

Question 9 (9 marks)

Instant ice packs are convinent sources of cooling, particularly in regions where refigeration is scarce. They rely on chemical reactions in order to rapidly cool synthetic materials that retain the low temperatures.

A particular instant ice pack is being used to calibrate a calorimeter. It undergoes the reaction shown below.

$$NH_2CONH_2(s) \rightarrow NH_2CONH_2(aq), \qquad \Delta H = +33.5\ kJ\ mol^{-1}$$

a. At SLC, a 150 g of $NH_2CONH_2(s)$ is dissolved in the calorimeter and there was a temperature change of 5.60 ℃. Calculate the calibration factor for the calorimeter in kJ ℃$^{-1}$. (2 marks)

$n(NH_2CONH_2) = \frac{m}{M_R} = \frac{150g}{60g/mol} = 2.5mol$

$q = n \times \Delta H = 2.5mol \times 33.5kJ$

$= 83.75kJ$

$CF = \frac{q}{\Delta T} = \frac{83.75kJ}{5.60°C} = 14.955kJ/°C$

$= 15.0kJ/°C$

b. A 2.50 g chocolate bar is combusted in the calorimeter and the temperature of the water increased by 15.5 ℃. Caluculate the energy content of the chocolate bar in $kJ\ g^{-1}$. (2 marks)

$q = CF \times \Delta T = 14.955kJ/°C \times 15.5°C$

$= 231.8kJ$

$\Delta H = \frac{q}{M} = \frac{231.8kJ}{2.5g} = 92.7kJ/g$

c. The calorimeter was electrically calibrated in a room at SLC and its noted that there is a small amount of heat loss occuring within the calorimeter. Explain how this discovery may impact the result you obtained in **part a.** (3 marks)

The electrical calibration will have increased the temperature of the calorimeter, and given there was heat loss it shows inadequate insulation. Since the chemical calibration was endothermic it decreased the temperature of the water. Therefore there would have been additional heat gain due to bad insulation. This would decrease the temperature change and according to $CF = \frac{q}{\Delta T}$, would increase the CF.

d. Suggest an improvement to the current set up that does not involve insualtion that would increase the reliability of the results. (2 marks)

Multiple trials should be run for both the calibration and the combustion of the chocolate bar. An average should be taken to minimise the effect of random errors such as the variable heat loss.

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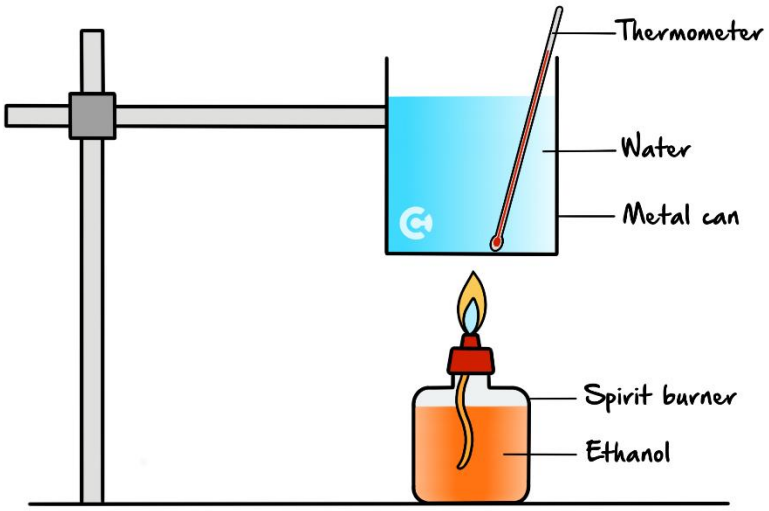
Question 10 (10 marks)

Jasmina and Swathi were trying to find the energy content of the peaches they grow over the summer break. However they were unable to use a calorimeter, so instead they decided to use the set up shown in the diagram below.



They wanted to calibrate the set up first through combusting ethanol. The spirit burner intially weighed 25.0 g. It then underwent complete combustion and the weight of the spirit burner was recorded to be 21.8 g. The beaker contained 300 g of water and increased in by 35.70 °C.

a.

i. Calculate the energy content of the ethanol in $kJ\ g^{-1}$. (2 marks)

$m(C_2H_5OH) = 25.0g - 21.8g = 3.2g$

$q = mC\Delta T = 300 \times 4.18 \times 35.7 = 44767.8\ J$

$= 44.77\ J$

$\Delta H = \frac{q}{m} = \frac{44.78kJ}{3.2g} = 13.99\ kJ/g$

$= 14.0kJ/g$

ii. Hence or otherwise, calculate the % heat loss in the current set up. (2 marks)

$\%.\ heat\ loss = \frac{29.6 - 14.0kJ/g}{29.6kJ/g} \times 100\% = 52.7\%$

The spirit burner was replaced with a dish holding the peaches and the set up was allowed to cool to room temperature.

The peaches weighed 5.0 g and was completely combusted. It was found to increase the temperature of the same 300 g of water by 15.2 ℃.

b.

i. Using the value obtained in **part a.i., c**alculate the energy content of the peaches in $kJ\ g^{-1}$. (3 marks)

$\%\ eff = 100 - 52.7 = 47.3\%$

$q = mc\Delta T = 300 \times 4.18 \times 15.2 = 19060.8\ J = 19.06\ kJ$

$q(\text{incl } \%\ eff) = \frac{19.06kJ}{0.473} = 40.298kJ$

$\Delta H = \frac{q}{n} = \frac{40.298kJ}{5g} = 8.060kJ/g$

$= 8.06kJ/g$

ii. Comment on the validity of this experiment. (2 marks)

The experiment is invalid. The peaches will have been combusted at a different distance from beaker. Additionally the peaches will combust over a larger area as opposed to the spirit burner which is targeted in one spot. Both of these extraneous variables render the experiment invalid.

iii. Suggest an improvement to the experiment that will provide more valid results. (1 mark)

- Combust a synthetic food (e.g candy) with a known energy content to calculate heat loss, placing it in the same dish as the peaches.
- Both the spirit burner and peaeches should be placed as close to the beaker as possible to ensure there is equal heat loss in both.

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