1. Glucose is a renewable energy source derived from the photosynthesis of plants. Many countries cultivate vast amounts of land for the growth of corn from which glucose is ultimately derived for the purpose of generating bioethanol, a renewable fuel. Below, in diagram 1, is a graph showing the amount of corn produced in the US from 1986 to 2020 in bushels. One bushel being equivalent to 25 kg of corn.

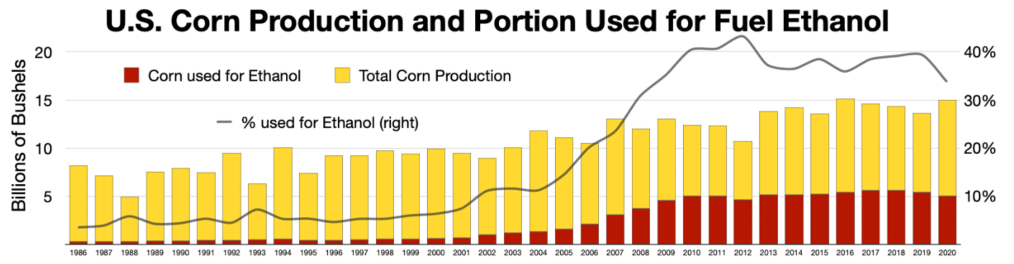


Diagram 1

a. Given that the molar heat of combustion of glucose is 2800 kJ/mol, write balanced thermochemical equations, states included, for:

i. Cellular respiration

__________$C_6H_{12}O_6\,(aq) + 6O_2(g) \rightarrow 6H_2O(l) + 6CO_2(g)\ \Delta H = -2800\ kJ$__________________*3 marks*

---- 1 mark for states

----1 mark for balanced equation

----1 mark for correct ΔH with units and sign

ii. Photosynthesis

__________ $6H_2O(l) + 6CO_2(g) \rightarrow C_6H_{12}O_6\,(aq) + 6O_2(g)\ \Delta H = +2800\ kJ$__________________*3 marks*

---- 1 mark for states

----1 mark for balanced equation

----1 mark for correct ΔH with units and sign

b. Write the balanced chemical equation, states included, for the anaerobic respiration known as alcohol fermentation and using oxidation numbers suggest why it is an incomplete or complete oxidation reaction.

$C_6H_{12}O_6\,(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$ ---- 1 mark

Oxidation number of C in glucose = O, Maximum oxidation number it can achieve is +4 ---- 1mark

C has an oxidation number of +2 in ethanol ----- 1 mark

Hence not fully oxidised.

____*3 marks*

c. Renewable and sustainable are sometimes used by non-chemists interchangeably.

i. Define each term

Renewable - *These fuels are derived from resources that can be regenerated or replenished relatively quickly compared to the rate at which they are consumed.*

Sustainable - *These fuels are produced, consumed, and managed in a manner that balances current energy needs with the needs of future generations, ensuring the preservation of ecosystems, biodiversity, and environmental protection.*

ii. Using bioethanol as an example and the information given in the stem of the question in diagram 1, label bioethanol as either renewable or non-renewable, sustainable or unsustainable **.** Explain your reasoning.

Renewable, unsustainable. ------ 2 marks if the explanation is plausible.
Renewable because it can be replenished within a relatively short period of time by the growing of crops so that is never depleted ------ 1 marks
Non-sustainable as it competes with ever growing demands for land to grow crops to feed populations. --- 1 mark

2. A food label for a plant based energy bar clearly states that 100 g of the food contains:

12.0 grams of total carbohydrates
- 4.0 grams of fibre
8.2 grams of fat/oil
9.0 grams of protein

a. What is the mass of available carbohydrate that can be used as an energy source if the athlete consumed 225 grams of the energy bar. Explain how you derived your answer.

12.0 – 4.0 = 8.0 grams ---- 1 mark
=> 8.0 X 225/100 = 18grams ---- 1 mark
Fibre is composed of cellulose, an indigestible carbohydrate that the body can not use as energy. 1 mark

b. Calculate the total energy available to the athlete when consuming 100 grams of the energy bar. *3 marks*

Energy from:

Carbohydrates => 8.0 X 16 = 1.3 X 10^2 kJ ------ 1 mark for correctly eliminating the fibre from the total carbohydrate content
Protein => 9.0 X 17 = 1.5 X 10^2 kJ
Fats /oils => 8.2 X 37 = 3.0 X 10^2 kJ ----- 1 mark for calculating all the energy values
Total = 5.8 X 10^2 kJ ----- 1 mark for correct total to the right number of sig figs.

3. A known mass of butane gas was burnt completely in pure oxygen at SLC. When all the mass of butane had finally reacted with the oxygen, 37.2 litres of a gaseous product was collected and its mass measured at 42.0 grams.

a. Identify the gaseous product. Show all working out. *3 marks*

Step 1 Calculate the mol of gas ---- 1 mark
=> 37.2 / 24.8 = 1.50
Step 2 find the molar mass of the gas ---- 1 mark
=> 42.0 / 1.5 = 28.0
Step 3 gas is CO. ---- 1 mark

b. Write a balanced chemical equation, states included, for the combustion reaction between butane and oxygen gas.

$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO(g) + 10H_2O(l)$
Correct formulae ---- 1 mark
Correct states (water as a liquid at SLC) ---- 1 mark
Balanced ---- 1 mark

c. Using your answer to b. above:

i. Identify the type of reaction taking place between the butane and oxygen gases at SLC.

______________________*Incomplete combustion*__________________________________ *1 mark*

ii. Describe the conditions under which the type of reaction you specified in i. above takes place.

Limited amount of oxygen, quick reaction time where reactant do not have time to mix properly
1 mark

d. Calculate the mass, in grams, of butane that was consumed during this reaction? Give your answer to the right number of significant figures.

Step 1 Use the equation given to b. above.
=> $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO(g) + 10H_2O(l)$
Step 2 Find the mol of gas produced as in question a. above.
=> 37.2 / 24.8 = 1.50
Step 3 Find the mol of butane used
=> 1.50 / 4 = 0.375 ------- 1 mark
Step 4 Find the mass of butane
=> 58.0 X 0.375 = 21.8 grams ------ 2 marks correct mass to the right number of sig figs

4. A mass of 4.65 grams of octane is mixed with 8.54 grams of oxygen at SLC and ignited. An exothermic reaction took place to produce a major greenhouse gas.

a. Write the balanced thermochemical equation, states included, for the reaction taking place.

The give away information in the stem of question is highlighted. The gas must be CO_2

At SLC states of octane and water are both liquid.

$2C_8H_{18}(l) + 25O_2 \rightarrow 16CO_2 + 18H_2O(l)$ --- 1 mark for each of the following, correct states, balanced equation and correct formulae.

b. Calculate the amount of energy, in kJ, that was released from the combustion of octane in oxygen gas.

Step 1 - Find the limiting reactant --- 1 mark for correct mol ---- 1 mark for identifying the limiting reactant.

=> mol of each reactant divided by its coefficient found in the balanced chemical equation.

=> n_{octane} = 4.65 / 114 = 0.0408

=> 0.0408 / 2 = 0.0204

=> n_{oxygen} = 8.54 / 32.0 = 0.267

=> 0.267 / 25 = 0.0107

Step 2 – Calculate the amount, in mol, of octane burnt ----- 1mark

=> 0.267 X 2/25 = 0.02136

Step 3 – Energy released

0.02136 X molar heat of combustion of octane

=> 0.02136 X 5460 kJ/mol (from data book) = 117 kJ ---- 1 mark Correct and to 3 sig figs.

c. The energy released from this reaction was used to heat a mass of water by 20.0°C. Calculate the mass of water in kg. *2 marks*

E = mass X 4.18 X 20.0 ---- 1 mark

4670 / (4.18 X 20.0) = 55.8 g or 5.58 X 10^{-2}kg ---- 1 mark (correct value and units)

d. The energy profile in figure 2 is of the reaction whose chemical equation is shown below.

A(g) + B(g) $\rightarrow$ AB(g).

600 kJ of energy was used to break bonds and whilst 500 kJ of energy was released during bond formation.

i. Complete the energy profile shown in figure 2. *2 marks*

---- 1 mark for correct shape

----- 1 mark for correct ΔH

ii. What type of thermochemical reaction is this?

___________*Endothermic*_________ *1 mark*

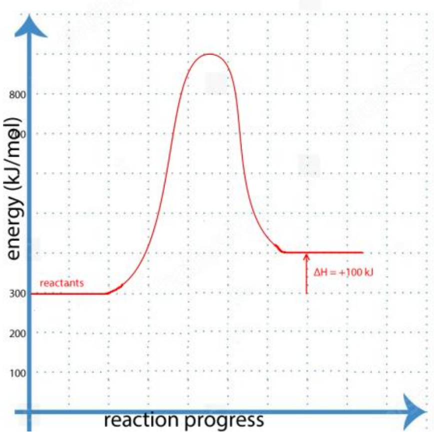


Figure 2

iii. Write the thermochemical equation for the reaction above.

A(g) + B(g) $\rightarrow$ AB(g) ΔH = +100 kJ --- 1 mark for correct equation ----1 mark correct ΔH

iv. Write the balanced thermochemical equation for the reaction
$2AB(g) \rightarrow 2A(g) + 2B(g)$

$2AB(g) \rightarrow 2A(g) + 2B(g)$ ΔH = -200 kJ

------ 1 mark for correct sign of the ΔH

------ 1 mark for correct value and units 200 kJ

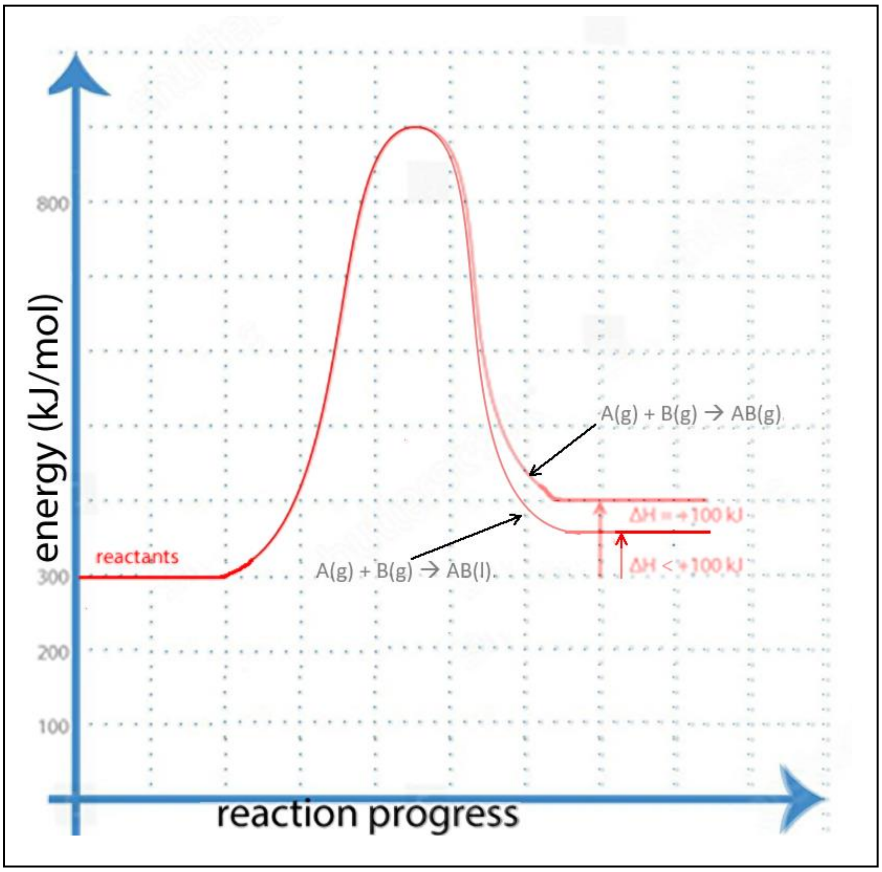
v. Consider the same <u>type</u> of reaction $A(g) + B(g) \rightarrow AB(l)$. How might the thermochemical equation for this reaction differ from that of $A(g) + B(g) \rightarrow AB(g)$. Explain.

The ΔH for the reaction $A(g) + B(g) \rightarrow AB(g)$ will be greater than that of $A(g) + B(g) \rightarrow AB(l)$.
---- 1mark

The reason is that less energy is needed to keep the product as a liquid than it is to keep it as a gas. So less energy will be given out during bond formation of reaction $A(g) + B(g) \rightarrow AB(g)$ than during $A(g) + B(g) \rightarrow AB(l)$ as the system is now composed of gas which requires a greater volume and energy. ---- 1 mark

Let's see if we can explain this with some pictures.

The reaction system that represents $A(g) + B(g) \rightarrow AB(l)$ has less energy after the reaction is complete. The liquid state occupies less volume and has less energy than the system represented by the reaction $A(g) + B(g) \rightarrow AB(g)$. The system $A(g) + B(g) \rightarrow AB(l)$ gives out more energy than $A(g) + B(g) \rightarrow AB(g)$ and hence has a lower value for its ΔH as shown in the diagram on the right.



5. A student used the setup shown in fig 2. to heat 500 mL of pure water, at SLC, using a spirit burner filled with ethanol. The temperature of the water increased by 40.0 ^{O}C.

Below is part of the method from the student's experimental report.

Weigh the spirit burner ------------ 110.24 g
Record the temperature of the water --- 25.0 °C
Light the spirit burner and heat the water for 10 minutes.
Put the flame out and record the:
- final temperature of the water ---- 50.0°C
- the mass of the spirit burner ----- 106.75 g

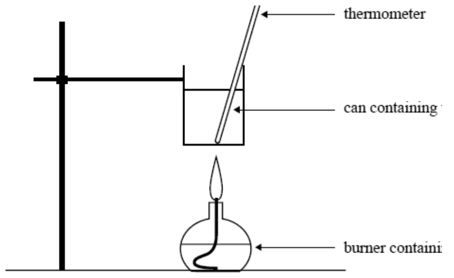


Figure 2

a. Calculate the amount of energy, in kJ, absorbed by the water, to the right number of significant figures. *3 marks*

Step 1 - Mass of water = 500 mL X 0.997 = 498.5g --------------- 1 mark (data book water density should be used if at SLC.)
Step 2 Find ΔT (50.0 – 25.0 = 25.0) ------- 1 mark
Step 2 - Enegry (J) = 4.18 X 498.5 X 25.0 = 52.1 kJ --------------- 1 mark (correct and to the right number of sig figs. Note 500 is considered to be 3 sig figs by VCAA)

b. Calculate total energy, in kJ, produced by the combustion of the ethanol in the spirit burner to the right number of significant figures. *2 marks*

Step 1 Find the mass of ethanol burnt
=> 110.24 – 106.75 = 3.49 ------- 1 mark
Step 2 Find Energy delivered by the complete combustion of ethanol at SLC. Refer to data book where you will find the heat of combustion, at SLC, of ethanol to be 29.6 kJ/g.
=> 3.49 X 29.6 = 103 kJ ----- 1 mark correct value and 3 sig figs.

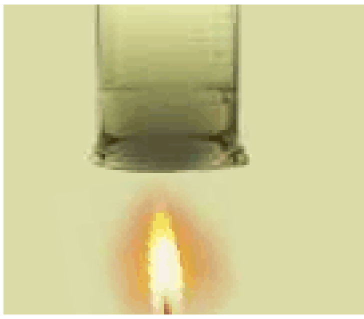


Diagram 1

c. Black soot was seen to form on the outside of the beaker, diagram 1, as the flame heated the water.

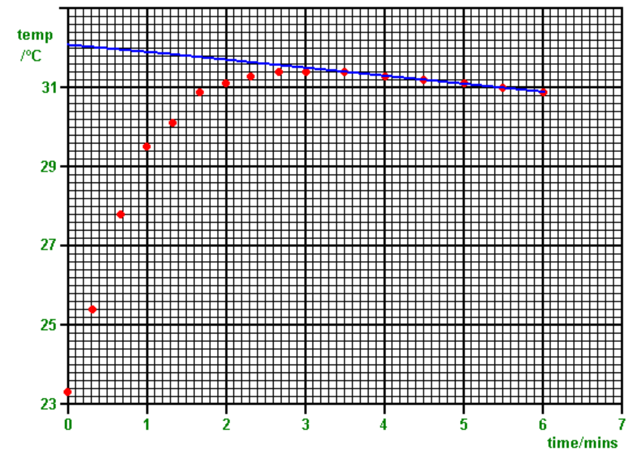
i. What can be deduced from this observation?
Incomplete combustion of ethanol ---- 1 mark

ii. How significant is this observation to the calculation of the answer to b. above. Explain. *2 marks*
Since the data booklet gives the values at SLC for complete combustion of fuels, or complete oxidation of fuels ----- 1 mark
the energy calculated would be higher than that delivered by incomplete combustion as less energy is delivered in the partial oxidation of the fuel than in complete oxidation. ----- 1 mark
Answer can be expressed in different ways but the two critical points had to be addressed.

d. Calculate the energy transformation efficiency of this method of heating. *2 marks*

(Useful energy/total energy) X 100 = efficicency of energy transformation ---- 1 mark
(52.1 / 103) X 100 = 50.6% ----- 1 mark

6. A current of 5.00 amps at 6.00 volts was passed through the heating coil of a solution calorimeter with 50 mL of distilled water. The current was allowed to flow for 1.00 minute and the temperature of the water was recorded every few seconds and the results presented as a graph, figure 3.



Temperature vs time graph

Figure 3

a. From the graph, figure 2, obtain a value for the change in temperature in °C.

1 mark

_______*8.6 – 8.9* ______

b. Calculate the calibration factor, in kj/°C, of the calorimeter to the correct number of significant figures *3 marks*

E = Vit ---- 1 mark

E(J) = 6.00 X 5.00 X 1.00 X 60 = 1800 J = 1.80 kJ------- 1 mark

E(J) = 1.80 / 8.9 = 0.20 kJ/°C ------ 1 mark for correct value and sig figs. (no need to express units as they were already given in the stem of the question.

c. An investigation was conducted to workout the thermochemical equation for the reaction shown below.

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) \quad \Delta H = ?\ kJ$$

An amount of 0.875 grams of calcium oxide was placed in the 50 mL of water and stirred. The water, originally at 25.00 °C reached a maximum of 32.20 °C.

i. Calculate the value of the ΔH for the above reaction and give its appropriate sign

4 marks

Step 1 - calculate the mol of CaO ------- 1 mark

=> 0.875 / 56.0 = 0.01563

Step 2 – Calculate the energy given out using the C_f ----- 1 mark

=> E(kJ) = 7.20 X 0.20 kJ/°C = 1.44 kJ

Step 3 – find energy released per mol of CaOm ---- 1 mark

=> 1.44kJ/0.01563

Step 4 – find the *ΔH ---- 1 mark for correct value and sign, no penalty was applied for incorrect sig figs.*

=> ΔH = - 92 kj (can also be expressed in kj/mol but since 2024 VCAA has changed the ΔH units to kJ)

ii. The literature indicates that the magnitude of the ΔH for the above reaction is 89 kJ. Compare your result with the literature value and suggest a reason for the discrepancy.

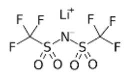
The calculated value is higher ------- 1 mark

Any plausible suggestion as to why is awarded the mark.

One possibility is that water is part of the reactants and as such is used up. Since the energy released is used to heat a smaller volume of water the temperature change is greater than would be expected. This will result in a higher calculated change in enthalpy (ΔH) ----- 1 mark

7. Lithium-ion batteries work poorly in extreme cold because the movement of lithium ions between the anode and cathode during discharge and recharge is severely hampered.

To make a rechargeable battery that would operate safely and maintain performance in the extreme cold, a physical chemist at Fudan University, selected ethyl acetate as a cold-tolerant electrolyte solvent. Ethyl acetate's freezing point is –84 °C, and it doesn't become viscous when it's cold. When combined with organic electrodes, the battery performed well at a temperature range from
50°C to -70°C. At -70°C the battery maintained 70% of its normal storage capacity.



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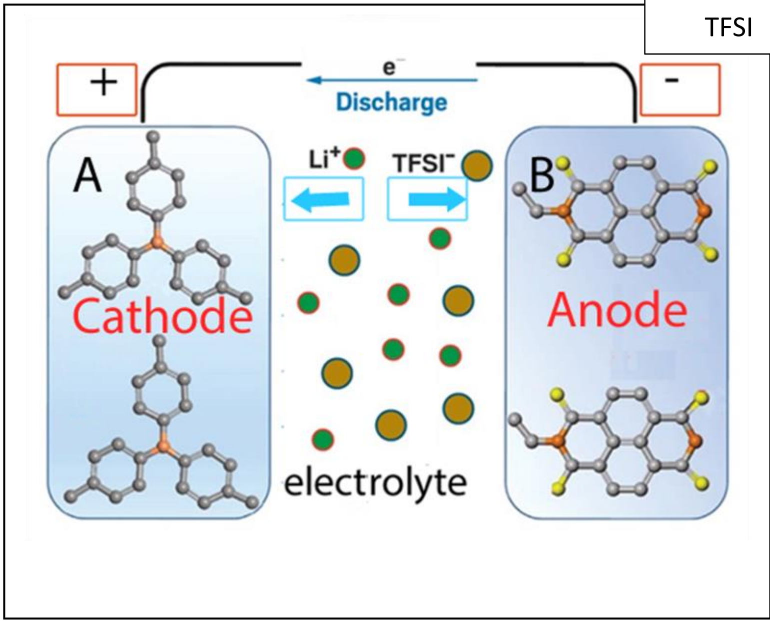
The battery is shown in figure 4.



a. Indicate, in the red boxes, the polarity of each electrode.
1 mark

b. Indicate in the blue boxes the direction of the ion movement.
1 mark

c. Which electrode is the:

i. Anode ___*B*_

ii. Cathode _*A*__

1 mark

d. Explain why ethyl acetate was chosen as the electrolyte and not a water based solution?

Ethyl acetate has a lower freezing point than water hence ----- 1 mark
it will hence will facilitate the movement of ions through the electrolyte at subzero temperatures. --- 1 mark

e. The viscosity of the electrolyte increases as the temperature decreases. Hence the amount of electrical energy a battery can store and subsequently release is severely limited at low temperatures. Explain why in terms of collision theory and activation energy.
Recharging is a chemical reaction that requires an input of energy. Ions are forced to move through the electrolyte, by an external power source, n the opposite direction to when the battery is discharging. An increase in viscosity slows the movement of ions down and hence slows the reactions taking place down. ---- 1 mark

At lower temperatures the proportion of particles with the required activation energy is very low. Also the activation of particles needed to move them through the electrolyte increases as noted above. ---- 1 mark

f. Below is the same cell as above (fig 4) but in recharge mode.

i. Indicate, in the red boxes, the polarity of each electrode.
ii. Indicate, in the blue boxes the direction of the ion movement.
Iii. Which electrode is the:

Anode _______

Cathode _____

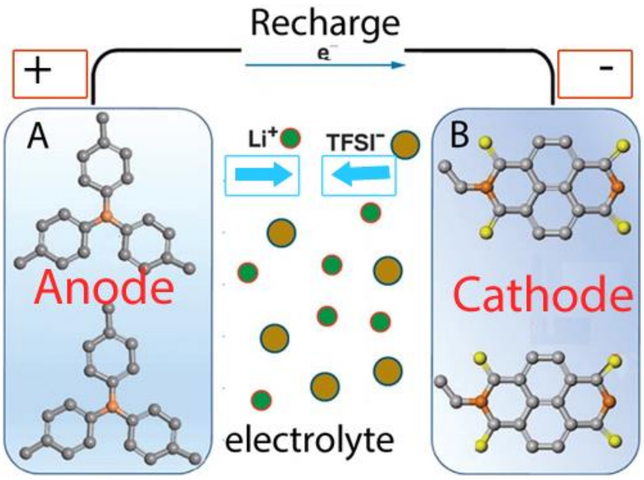


Figure 2