Neap

Diagnostic Topic Test 2024

VCE Chemistry Units 3&4

Suggested Solutions

Test 1: What are the current and future options for supplying energy?

- Carbon-based fuels
- Measuring changes in chemical reactions

SECTION A – MULTIPLE-CHOICE QUESTIONS

Question 1 C

C is correct. Fuels are energy-rich substances from which energy can be conveniently released.

A is incorrect. This defines a renewable energy source.

B is incorrect. This describes a fossil fuel.

D is incorrect. Many substances react to produce energy, but this does not mean they function as a fuel.

Question 2 D

D is correct. Fossil fuel formation takes millions of years, whereas biofuels can be generated in a matter of months.

A is incorrect. Energy is required for the isolation (often distillation) of the compound irrespective of its source.

B is incorrect. The compound in a biochemical fuel, or the same compound derived from fossil fuels, would produce the same amount of energy per mole burnt.

C is incorrect. Both fossil fuel formation and biofuel production occur due to natural processes; for example, the action of microbes on complex compounds.

Question 3 B

B is an incorrect conclusion and so is the required response. The activation energy of the reverse reaction is equivalent to the energy from the level at P to the state of maximum energy; that is, $x + y - z$ and not $x + y$.

A is a correct conclusion and so is not the required response. As $H_P > H_R$, there is residual energy in the products after the bonds are broken in the reactants.

C is a correct conclusion and so is not the required response. The heat of reaction is given by $H_P - H_R$, which is equal to $z - x$.

D is a correct conclusion and so is not the required response. After the bonds in the reactants are broken, the system reaches a maximum energy state equivalent to $x + y$. When the products form, energy is released, leaving the energy of the system equivalent to z. Thus, the energy released after the state of maximum energy is $x + y - z$.

Question 4 B

energy density of methane = 55.6 kJ g^{-1}

energy density of ethanol = 29.6 kJ g^{-1}

Therefore methane has the larger energy density. Each mole of methane produces one mole of CO_2 and 890 kJ of energy. Each mole of ethanol produces two moles of CO_2 and 1360 kJ mol^{-1}; that is, for each mole of CO_2, 680 kJ of energy is produced (less than the value for methane).

Question 5 A

The relevant equation is $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$. The reaction releases energy; that is, it is exothermic. The oxidation numbers are as follows: C in $C_6H_{12}O_6$ is 0, C in CO_2 is +4. There is an increase in oxidation number, hence oxidation of the carbon atom is occurring.

Question 6 D

$$\text{CF} = \frac{E}{\Delta T} = \frac{VIt}{\Delta T} = \frac{5.31 \times 1.16 \times 3.00 \times 60}{0.66} = 1680 \text{ J °C}^{-1} = 1.68 \text{ kJ °C}^{-1}$$

Question 7 C

$CH_3OH(g) \rightarrow CH_3OH(l)$ is an exothermic process.

$CH_3OH(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$ is also exothermic.

Adding the two equations and so adding their ΔH values produces a larger value for the energy released in the $CH_3OH(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$ reaction compared to the $CH_3OH(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$ reaction.

Question 8 B

B is correct, and **A** and **C** are incorrect. The relevant calculations are as follows.

$$n(\text{Zn}) = \frac{m}{M} = \frac{0.546}{65.4} = 8.35 \times 10^{-3} \text{ mol}$$

$(Ag^+) = c \times V = 0.050 \times 0.050 = 2.50 \times 10^{-3}$ mol

2.50×10^{-3} mol of Ag^+ will react with 1.25×10^{-3} mol of Zn. Zn is therefore in excess by $(8.35 - 1.25) \times 10^{-3} = 7.10 \times 10^{-3}$ mol.

D is incorrect. The limiting reagent depends on the relative amounts of substance needed for reaction according to the balanced equation, and not on the states of the reactants.

Question 9 D

0.165 mol releases 225 kJ. 1.0 mol releases *X* kJ.

$$X = \frac{225}{0.165} = 1364 \text{ kJ}$$

This is close to the heat of combustion of ethanol (by reference to the Data Booklet).

Question 10 A

A is correct. A fuel releases energy and so the reaction is exothermic. I, II and IV show profiles for exothermic reactions. A fuel releases a large amount of energy and has a relatively low activation energy. This is shown in profile I.

B is incorrect. This profile has low energy release and a high activation energy.

C is incorrect. This is the profile of an endothermic reaction.

D is incorrect. This profile has a low activation energy, but also has low energy release.

SECTION B

Question 1 (9 marks)

a. **i.** $6CO_2(g) + 6H_2O(l) \xrightarrow[\text{light}]{\text{chlorophyll}} C_6H_{12}O_6(aq) + 6O_2(g)$ 2 marks

1 mark for the correct reactants/products.
1 mark for the correct balancing/states.

ii. The fuel is 'wet' and so does not produce large amounts of energy per gram of fuel. 1 mark

iii. $n(C_6H_{12}O_6) = \frac{m}{M} = \frac{9.0}{180.0}$ mol 1 mark

$n(CO_2) = 2 \times n(C_6H_{12}O_6) = 2 \times \frac{9.0}{180.0} = 0.10$ mol 1 mark

$V(CO_2)_{SLC} = n \times 24.8 = 0.10 \times 24.8 = 2.5$ L 1 mark

b. **i.** Carbon dioxide is used in photosynthesis to make glucose, which in turn is used to make ethanol. 1 mark

Ethanol releases the carbon dioxide on combustion. Therefore, there is no net addition of carbon dioxide to the atmosphere. 1 mark

ii. *For example, any one of:*

- Deforestation and land clearing for large-scale production of crops to produce bioethanol is of concern, as this will endanger habitats and lead to possible erosion and land degradation.
- Current vehicles cannot use more than a 10% ethanol-in-petrol mix. New vehicles would need to be designed and built to run on ethanol.

1 mark

Question 2 (10 marks)

a. **i.** $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = -890$ kJ mol^{-1} 2 marks

1 mark for the correct equation.
1 mark for the correct ΔH value.

ii. energy for 100% efficiency = $m \times c \times \Delta T = 750 \times 4.18 \times (100 - 15)$ J 1 mark

energy for 65% efficiency $= 750 \times 4.18 \times (100 - 15) \times \frac{100}{65} = 409\,962 \text{ J} = 410 \text{ kJ}$ 1 mark

1 mol of methane = 16.0 g releases 890 kJ when burnt

x g releases 409.96 kJ

$x = 7.37$ g 1 mark

b. **i.** Energy efficiency is a measure of the amount of energy produced in the required form as a percentage of the initial energy provided. For the coal-fired power station,

$\%\text{ efficiency} = \frac{\text{amount of electrical energy}}{\text{amount of energy in coal}} \times \frac{100}{1}$. 1 mark

ii. Energy conversion from chemical in fuel to electrical output requires one less step in the gas-fired power station. Fewer steps means less energy loss, and so the overall efficiency of conversion is increased. 1 mark

iii. *For example, any one of:*

- The large volumes of CO_2 generated contribute to the enhanced greenhouse effect and consequent global warming.
- SO_2 generated from burning coal may react with rainwater to form acid rain, which can damage plants and corrode buildings.

1 mark

c. Methane may be obtained from natural gas. This source provides a non-renewable source of methane as it is a fossil fuel that is formed over millions of years. 1 mark

Methane may also be obtained from the anaerobic decomposition of organic matter such as sewage. This methane, biogas, is a renewable source as it can be generated at about the same rate as it is used. 1 mark

Question 3 (6 marks)

a. 0.286 g with energy content 23.6 kJ g^{-1} gives $0.286 \times 23.6 = 6.7496$ kJ 1 mark

$$CF = \frac{E}{\Delta T} = \frac{6.7496}{7.65} = 0.882 \text{ kJ °C}^{-1}$$ 1 mark

b. Using the Data Booklet values for food energies, the energy content of 1.0 g of cashew nut is $(0.28 \times 16) + (0.18 \times 17) + (0.47 \times 37) = 24.9$ kJ. 2 marks

1 mark for using the correct values in the calculation.
1 mark for the correct answer.

c. *Any one of:*

Assuming the **part b.** value to be correct, the experimental value is lower than expected. Explanation I could account for this. 1 mark

If the sample was not crushed sufficiently to increase surface area for reaction, the reaction may have been incomplete and so a lower energy content would have been determined. 1 mark

OR

Assuming the **part b**. value to be correct, the experimental value is lower than expected. Explanation II would not account for this. 1 mark

If less water was used in the calorimeter the recorded temperature rise would be larger than expected, leading to a higher (not lower) calculated value for energy content. 1 mark

OR

Assuming the **part b.** value to be correct, the experimental value is lower than expected. Explanation III could not account for this. 1 mark

Cellulose will burn in the calorimeter to provide energy, and so this cannot explain the lower value in **part a.** *(cellulose cannot be digested by humans and so does not serve as an energy source when consumed in the diet).* 1 mark