

**Energetics – A2 Chemistry P2**

1. No.8

**0 8**

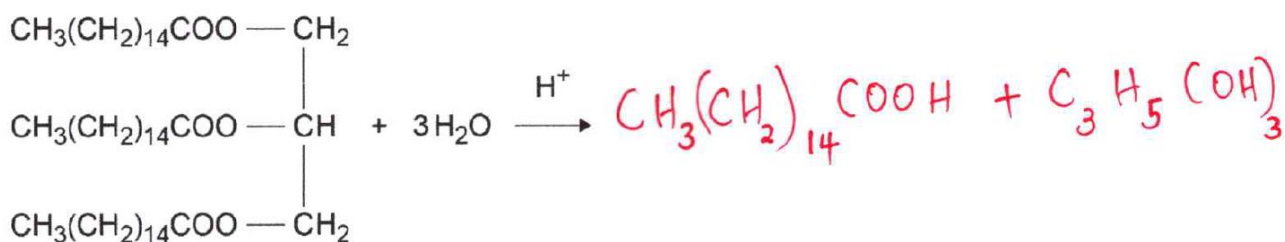
This question is about biofuels.

Palmitic acid,  $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$ , can be made by hydrolysis of the triester in palm oil under acidic conditions.

Palmitic acid can be used as a biofuel.

**0 8 . 1**

Complete the equation for the hydrolysis of the triester in palm oil under acidic conditions.

**[2 marks]****0 8 . 2**

Palmitic acid burns in air.

In a calorimetry experiment, combustion of 387 mg of palmitic acid increases the temperature of 0.150 kg of water from 23.9 °C to 37.5 °C

Calculate a value, in  $\text{kJ mol}^{-1}$ , for the enthalpy of combustion of palmitic acid in this experiment.

Give your answer to the appropriate number of significant figures.

The specific heat capacity of water is  $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

[5 marks]

① Convert mass of water to g.

$$0.150 \text{ kg} \times 1000 = 150 \text{ g}$$

② Temperature change  $\Delta T$ 

$$= 37.5 - 23.9$$

$$= 13.6^\circ\text{C}$$

③ Heat absorbed by water.

$$q = m \times c \times \Delta T$$

$$150 \times 4.18 \times 13.6$$

$$= 8527.2 \text{ J}$$

④ Mass of Palmitic acid.

$$387 \text{ mg} \times 1 \text{ g} / 1000 \text{ mg} = 0.387 \text{ g}$$

$$0.387 \text{ g}$$

Molar mass of palmitic acid.

$$= 256$$

Moles of palmitic acid =

$$\frac{0.387}{256} = 0.00151 \text{ mol}$$

Enthalpy of combustion per mole of palmitic acid.

$$\Delta H_c = q/n$$

$$= \frac{8527.2}{0.00151} \div 1000 = -5641$$

Enthalpy of combustion -5640 kJ mol<sup>-1</sup>

**08.3**

State how the value calculated in Question 08.2 is likely to differ from data book values.

Give one reason, other than heat loss, for this difference.

**[2 marks]**

Difference It is less exothermic.

Reason It undergoes incomplete combustion.

**08.4**

A sample of a different biofuel, made from sewage sludge, is found to contain 37.08% carbon, 5.15% hydrogen and 24.72% oxygen by mass. The rest of the sample is sulfur.

Calculate the empirical formula of this biofuel.

**[3 marks]**

Mass of C = 37.08  
H = 5.15  
O = 24.72

Mass of sulfur =  
 $100 - (37.08 + 5.15 + 24.72)$   
= 33.05

|                                      | C                                   | H          | O           | S           |
|--------------------------------------|-------------------------------------|------------|-------------|-------------|
| Mass                                 | 37.08 g                             | 5.15 g     | 24.72 g     | 33.05 g     |
| Molar mass                           | 12.01 g/mol                         | 1.01 g/mol | 16.00 g/mol | 32.07 g/mol |
| Moles                                | 3.09 mol                            | 5.10 mol   | 1.55 mol    | 1.03 mol    |
| Divide moles by smaller moles        | 1.03                                | 1.03       | 1.03        | 1.03        |
| Multiple by 2 because of non integer | 3                                   | 5          | 1.5         | 1           |
|                                      | 3 × 2 = 6                           | 5 × 2 = 10 | 1.5 × 2 = 3 | 1 × 2 = 2   |
| Empirical formula                    | <u><math>C_6H_{10}O_3S_2</math></u> |            |             |             |

**08.5**

Complete combustion of the biofuel made from sewage sludge produces the greenhouse gas carbon dioxide.

Suggest **one** other possible environmental problem with the complete combustion of this biofuel.

State the formula of the pollutant responsible for this problem.

**[2 marks]**

Environmental problem It causes acid rain.

Formula  $SO_2$

**0 8 . 6** Ethanol is a biofuel that can be produced by the fermentation of glucose.



Glucose has the structural formula shown.

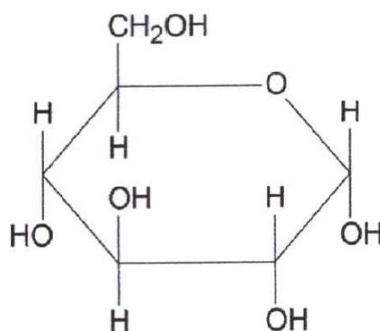


Table 3 shows some mean bond enthalpy values.

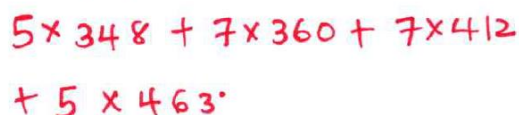
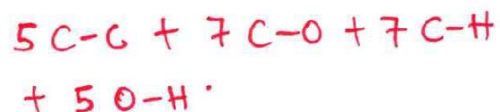
Table 3

|                                           | C-H | C-C | C-O | C=O | O-H |
|-------------------------------------------|-----|-----|-----|-----|-----|
| Mean bond enthalpy / kJ mol <sup>-1</sup> | 412 | 348 | 360 | 805 | 463 |

Use the equation and the data in Table 3 to calculate an approximate value of  $\Delta H$  for the fermentation of glucose. For this calculation you should assume that all the substances are in the gaseous state.

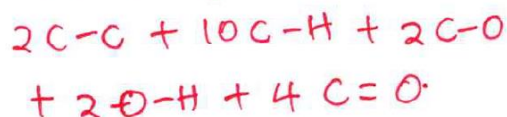
[3 marks]

① Bonds broken:



$$= 9459 \text{ kJ}$$

② Bonds formed:



$$2 \times 348 + 10 \times 412 + 2 \times 360 + 2 \times 463 + 4 \times 805 = 9682 \text{ kJ}$$

$$\Delta H = \text{Bonds broken} - \text{Bonds formed}$$

$$= 9459 - 9682$$

$$= -223 \text{ kJ}$$

$$\Delta H = -223 \text{ kJ mol}^{-1}$$

08.7

The carbon dioxide produced from fermentation can be reacted with steam to make more ethanol.

The equation for this reaction is



**Table 4** shows some standard enthalpies of formation.

**Table 4**

|                                           | $\text{CO}_2(\text{g})$ | $\text{O}_2(\text{g})$ | $\text{C}_2\text{H}_5\text{OH}(\text{g})$ | $\text{H}_2\text{O}(\text{g})$ |
|-------------------------------------------|-------------------------|------------------------|-------------------------------------------|--------------------------------|
| $\Delta_f H^\ominus / \text{kJ mol}^{-1}$ | -394                    | 0                      | -235                                      | -242                           |

Use the data in **Table 4** to calculate a standard enthalpy change value for this reaction.

[2 marks]

- ① Sum of enthalpy of formation of products.  
 $(-235) + (3 \times 0) = -235 \text{ kJ mol}^{-1}$
- ② Sum of enthalpy of formation of reactants.

$$(2 \times -394) + (3 \times -242) = -1514 \text{ kJ mol}^{-1}$$

$$\Delta H = -235 - (-1514) = +1279 \text{ kJ mol}^{-1}$$

Standard enthalpy change +1279 kJ mol<sup>-1</sup>

## 2. No.5

0 5

The molar enthalpy of vaporisation ( $\Delta H_{\text{vap}}$ ) of a liquid is the enthalpy change when one mole of liquid is converted to vapour at the boiling point of the liquid.

A student does an experiment to determine  $\Delta H_{\text{vap}}$  for water.

The student:

- places a large beaker on a balance
- pours 500 cm<sup>3</sup> of water into the beaker
- uses a 2.4 kW heater to raise the temperature of the water to 100 °C
- records the mass of the beaker and hot water
- uses the 2.4 kW heater to boil the water for 100 s
- records the mass of the beaker and remaining water.

The loss in mass is 103 g

0 5

1

Calculate  $\Delta H_{\text{vap}}$  for water.

[1 kW = 1 kJ s<sup>-1</sup>]

[3 marks]

(i) Energy supplied by heater in 100 sec.

$$\begin{aligned}\text{Energy} &= \text{Power} \times \text{time} \\ &= 2.4 \text{ kW} \times 100 \text{ sec} \\ &= 240 \text{ kJ}\end{aligned}$$

(ii) Mass of water vaporised  
= 103 g.

(iii) Molar enthalpy of vaporisation =  
 $\frac{\text{Energy supplied}}{\text{Moles of water vaporized}}$

(iv) Moles of water vapourised =  
 $\frac{\text{Mass of water vaporised}}{\text{Molar mass of water}}$

$$\frac{103 \text{ g}}{18 \text{ g/mol}}$$

$$= 5.72 \text{ mol}$$

Molar enthalpy of  
Vaporisation

$$= \frac{240 \text{ kJ}}{5.72 \text{ mol}}$$

$$= 41.9$$

$$= 42$$

$$\Delta H_{\text{vap}} \underline{42} \text{ kJ mol}^{-1}$$

**Table 2** shows some data about three compounds that all contain the same number of electrons.

**Table 2**

| Compound          | $\text{CH}_3\text{CH}_2\text{OH}$ | $\text{CH}_3\text{CH}_2\text{NH}_2$ | $\text{CH}_3\text{OCH}_3$ |
|-------------------|-----------------------------------|-------------------------------------|---------------------------|
| Boiling point / K | 352                               | 290                                 | 248                       |

0 5 . 2

All three compounds in **Table 2** are polar.

Ethanol is the most polar and ethylamine is the least polar.

Explain why all three molecules are polar and why ethylamine is the least polar. In your answer refer to the shapes around, and relative electronegativities of, the most electronegative atoms.

[4 marks]

Because they contain polar bonds due to electronegativity difference between atoms. Ethylamine is least polar because electronegativity difference between nitrogen and hydrogen is smaller than difference between oxygen and hydrogen or carbon and oxygen. The shape of ethylamine molecule contributes to its low polarity. The nitrogen atom in ethylamine has a lone pair of electrons which creates a bent shape around nitrogen atom; this reduces overall dipole moment of the molecule.  $\text{CH}_3\text{CH}_2\text{OH}$  and  $\text{CH}_3\text{OCH}_3$  both are V-shaped. These shapes are non symmetrical.

0 5 . 3

Explain the trend in the boiling points of the three compounds.

Refer to the intermolecular forces in all three compounds in your answer.

[3 marks]

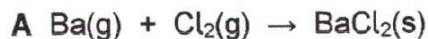
Ethanol has the highest boiling point because it can form hydrogen bonds, which are the strongest type of intermolecular force. Ethylamine can also form hydrogen bonds, but the hydrogen bonds are weaker than those in ethanol because nitrogen is less electronegative than oxygen. Methoxymethane cannot form hydrogen bonds, so it has the lowest boiling point.

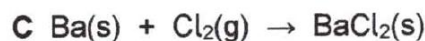
## 3. No.10

1 0

Which reaction has a standard enthalpy change equal to the standard enthalpy of formation for barium chloride?

[1 mark]


☐

☐

☒

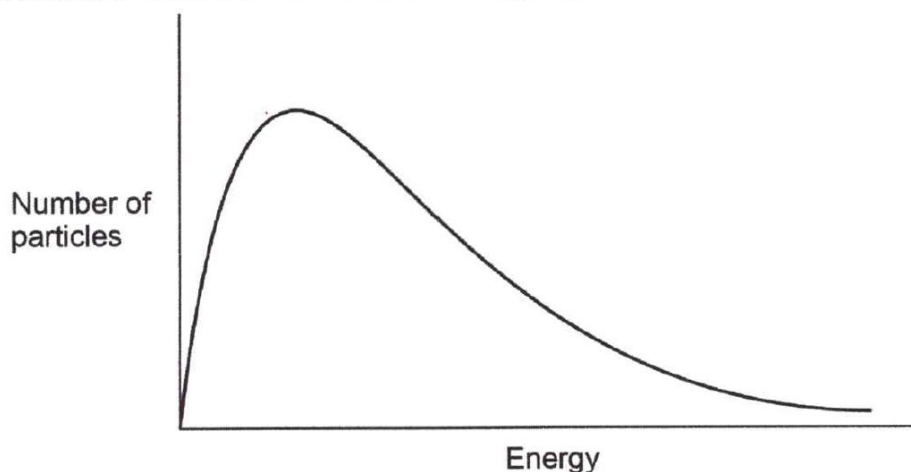
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$\Delta H_f$  - enthalpy change when one mole of a compound is formed from its elements in their standard states

## 4. No.11

1 1

This is a Maxwell-Boltzmann distribution for a gaseous reactant.



What is represented by the total area under the curve?

[1 mark]

A total energy of the particles

☐

B activation energy for the reaction

☐

C total number of reacting particles

☐

D total number of particles present

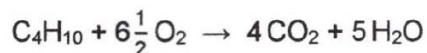
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Each small strip represents number of particles with specific energy change. Summing all strips gives total number of particles.

5. No.28

2 8

The equation for the complete combustion of butane is



What is the mole fraction of butane in a mixture of butane and oxygen with the minimum amount of oxygen needed for complete combustion?

[1 mark]

A 0.133

☒

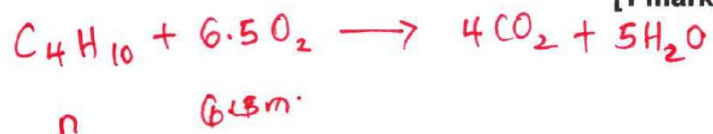
B 0.153

☐

C 0.167

☐

D 0.200

☐


moles of butane =  $6.5n$

Total number of moles in mixture  
 $= n + 6.5n = 7.5n$

mole fraction of ( $\text{C}_4\text{H}_{10}$ )

$$x_{\text{C}_4\text{H}_{10}} = \frac{n}{7.5n} = \frac{1}{7.5}$$

$$x_{\text{C}_4\text{H}_{10}} = 0.133$$