AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level
APPLIED SCIENCE

Unit 11 Controlling Chemical Processes

Tuesday 14 June 2016 Afternoon Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- a pencil
- a ruler
- a calculator.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show the working of your calculations.

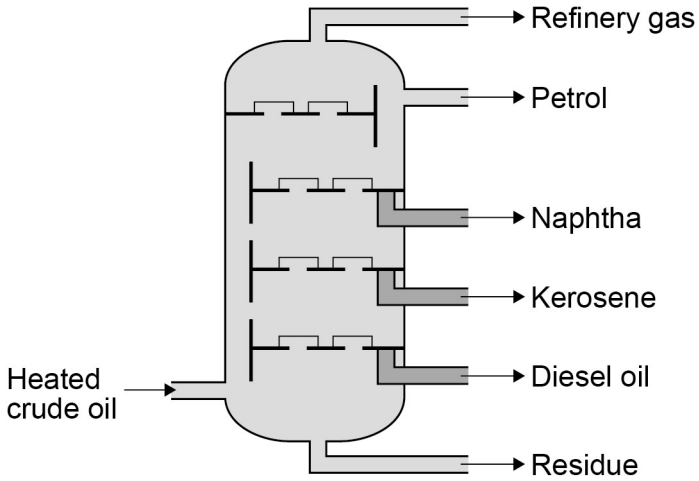
Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.
- You will be marked on your ability to
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.
- You are expected to use a calculator where appropriate.

Answer **all** questions in the spaces provided.

1 Industrial chemists working at a petrochemical company use fractional distillation to separate crude oil into products such as petrol and diesel.

1 (a) The raw material, crude oil, is heated and the vapour is fed into a fractionating tower where the separation occurs. **Figure 1** shows a fractionating tower.

Figure 1



Define the term **raw material**.

[1 mark]

_____

_____

1 (b) Costs involved in industrial processes can be classified as:

capital costs **direct costs** **indirect costs**.

1 (b) (i) Define the term **capital costs**.

[1 mark]

_____

_____

1 (b) (ii) Identify **two** direct costs, **one** indirect cost, and **one** capital cost of fractional distillation.
[4 marks]

Direct cost 1 _____

Direct cost 2 _____

Indirect cost _____

Capital cost _____

1 (c) (i) Fractional distillation is a continuous process.

Define the term **continuous process**.
[2 marks]

_____

_____

_____

_____

1 (c) (ii) Some processes can be batch processes.

Define the term **batch process**.
[2 marks]

_____

_____

_____

_____

1 (c) (iii) A continuous process often costs less than a batch process.

Give **one** other advantage of a continuous process compared to a batch process.
[1 mark]

_____

_____

Question 1 continues on the next page

1 (d) Some products from crude oil are cracked to produce more useful shorter-chain alkanes and alkenes.

1 (d) (i) Complete the following equation for the cracking of an alkane in fuel oil, $C_{35}H_{72}$, to produce decane, $C_{10}H_{22}$, and ethene, C_2H_4

[2 marks]

$$2C_{35}H_{72} \rightarrow \_\_\_\_\_C_{10}H_{22} + \_\_\_\_\_C_2H_4$$

1 (d) (ii) Ethene is an important starting material for many polymers. The reaction shown below is one stage in the manufacture of the polymer PVC, poly(chloroethene).

CH_2ClCH_2Cl	$\rightarrow$	$CH_2{=}CHCl$	+	HCl
1,2-dichloroethane		chloroethene		

Calculate the relative molecular masses of 1,2-dichloroethane and chloroethene.
(Relative atomic masses: C = 12; H = 1; Cl = 35.5)

[2 marks]

M_r 1,2-dichloroethane _____

M_r chloroethene _____

1 (d) (iii) Calculate the mass of 1,2-dichloroethane needed to make 9 kg of chloroethene. Assume that the yield of the reaction is 100%.

[3 marks]

_____

_____

_____

Mass = _____

1 (d) (iv) The yield of this reaction will actually be lower than 100%.

Suggest **one** reason why.

[1 mark]

_____

_____

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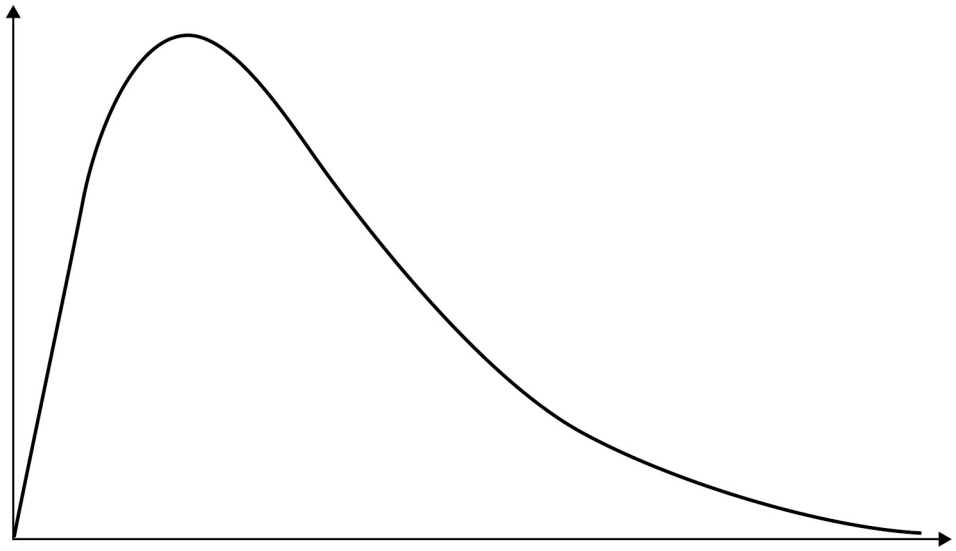
2 In industrial processes, research chemists must find conditions that produce a satisfactory yield in a short time.

2 (a) Changing the temperature of a reaction mixture can have a dramatic effect on the reaction rate.

Figure 2 shows a Maxwell–Boltzmann curve of the distribution of the energies of particles. This can be used to explain why an increase in temperature increases the rate of a reaction.

Figure 2



2 (a) (i) Add the correct labels to the axes on the graph in **Figure 2**.

[2 marks]

2 (a) (ii) On **Figure 2**, sketch the curve you would expect for the same particles at a higher temperature.

[2 marks]

Question 2 continues on the next page

2 (a) (iii) Define the term **activation energy** and use the idea of activation energy to explain why an increase in temperature increases the rate of a reaction.

You will be assessed on the quality of written communication in your answer to this question.

[5 marks]

Extra space (if needed) _____

2 (b) The rate of a reaction can change depending on the concentrations of the reactants.

A research chemist is studying a reaction that has three reactants, **L**, **M** and **N**, in solution.

$$\mathbf{L} + \mathbf{M} + \mathbf{N} \rightarrow \mathbf{P} + \mathbf{Q}$$

She finds that the rate of the reaction is:

- zero order with respect to **P** and **Q**
- first order with respect to **L** and **M**
- second order with respect to **N**.

2 (b) (i) Circle the correct overall order for this reaction.

[1 mark]

1 **2** **3** **4** **5**

2 (b) (ii) Define the term **zero order**.

[2 marks]

2 (b) (iii) Write the rate equation for the reaction between **L**, **M** and **N**.

[3 marks]

Question 2 continues on the next page

2 (b) (iv) A different reaction has the rate equation:

$$\text{rate} = k[A]^2[B]$$

Use this rate equation to complete **Table 1**.

[3 marks]

Table 1

Experiment	Initial [A] (mol dm^{-3})	Initial [B] (mol dm^{-3})	Initial rate (mol dm^{-3} s^{-1})
1	1.60×10^{-4}	3.00×10^{-3}	1.70×10^{-1}
2	4.80×10^{-4}	3.00×10^{-3}	
3		3.00×10^{-3}	8.84×10^{-2}
4	1.60×10^{-4}		4.59×10^{-1}

2 (b) (v) Use the data from Experiment 1 in **Table 1** to calculate a numerical value for the rate constant, *k*. Give your answer to 3 significant figures.

[3 marks]

Rate constant = _____

2 (b) (vi) Work out the unit of *k*.

[1 mark]

22

3 Catalysts are often used by chemical engineers to increase efficiency. Catalysts increase efficiency by making a reaction occur at a lower temperature.

3 (a) (i) Define the term **catalyst**.

[2 marks]

3 (a) (ii) Explain how a catalyst works. Use the idea of activation energy.

[2 marks]

3 (b) The decomposition of hydrogen peroxide to oxygen and water occurs quickly at room temperature if it is catalysed by manganese dioxide:

$$\underset{\text{hydrogen peroxide}}{2H_2O_2(aq)} \rightarrow \underset{\text{oxygen}}{O_2(g)} + \underset{\text{water}}{2H_2O(l)}$$

The effect of temperature changes on this reaction can be monitored by doing several experiments at different temperatures. In each experiment, the volume of gas produced over time is measured.

3 (b) (i) List the apparatus that could be used in these experiments.

[3 marks]

Question 3 continues on the next page

3 (b) (ii) Describe how a chemist would do these experiments.
You will be assessed on the quality of written communication in your answer to this question.

[5 marks]

Extra space (if needed) _____

3 (b) (iii) How could the chemist make sure that the results were reliable?

[2 marks]

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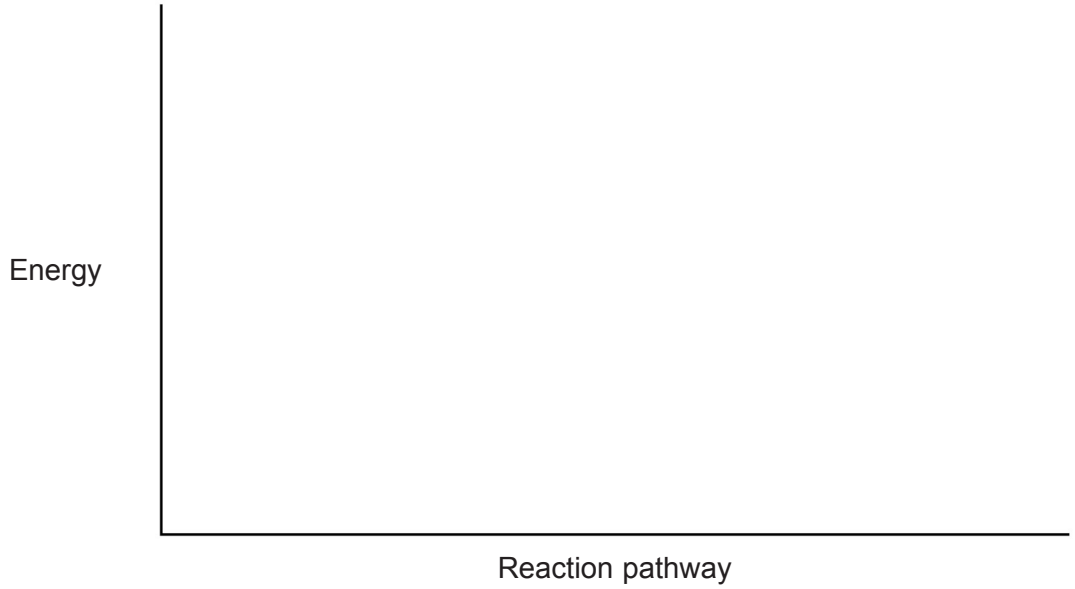
Turn over for the next question

4 Chemists working at a space agency need to use reactions that are highly exothermic. These exothermic reactions will provide power for their space missions.

4 (a) On **Figure 3** draw the reaction profile you would expect for an exothermic reaction.

[3 marks]

Figure 3



4 (b) Many space missions use liquid fuels such as methylhydrazine, CH_3NHNH_2, with oxidising agents such as dinitrogen tetroxide, N_2O_4

$$4CH_3NHNH_2(l) + 5N_2O_4(l) \rightarrow 4CO_2(g) + 12H_2O(l) + 9N_2(g)$$

4 (b) (i) Define the term **oxidise**.

[1 mark]

_____

_____

4 (b) (ii) What is the oxidation number of nitrogen in the following molecules?

[2 marks]

N_2O_4 _____

N_2 _____

4 (b) (iii) Methylhydrazine is toxic and corrosive. The chemists wear goggles as a safety precaution.

Suggest **one** other suitable safety precaution that the chemists should take.

[1 mark]

_____

_____

4 (c) (i) The enthalpy change for the oxidation of methylhydrazine can be worked out indirectly by using enthalpy of formation data and Hess's Law.

Define the term **enthalpy of formation**.

[3 marks]

_____

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_____

Question 4 continues on the next page

4 (c) (ii) Complete an appropriate Hess's Law cycle to show how you would calculate the enthalpy change of the reaction below using enthalpy of formation data.

[3 marks]

$$4CH_3NHNH_2(l) + 5N_2O_4(l) \rightarrow 4CO_2(g) + 12H_2O(l) + 9N_2(g)$$

4 (c) (iii) Calculate the enthalpy change when one mole of methylhydrazine is oxidised by dinitrogen tetroxide. Use the enthalpy of formation data in **Table 2**.

[4 marks]

Table 2

Substance	CH_3NHNH_2	N_2O_4	CO_2	H_2O
Enthalpy of formation (kJ mol^{-1})	+53	–20	–393	–286

Enthalpy change = _____

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5 Sulfuric acid is manufactured in the Contact Process. An industrial chemist works for a company that manufactures sulfuric acid. She must consider reaction conditions to ensure optimum efficiency. One of the reactions involved is shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

5 (a) If the Contact Process occurs in a closed system, a homogeneous equilibrium is established.

Define the term **homogeneous**.

[2 marks]

5 (b) (i) State Le Chatelier's principle.

[2 marks]

5 (b) (ii) Use Le Chatelier's principle to work out what effect an increase in temperature will have on the yield of sulfur trioxide, SO_3.

Explain your answer.

[3 marks]

5 (b) (iii) Under what circumstances does pressure affect the yield of an equilibrium reaction?

[1 mark]

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END OF QUESTIONS

There are no questions printed on this page

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