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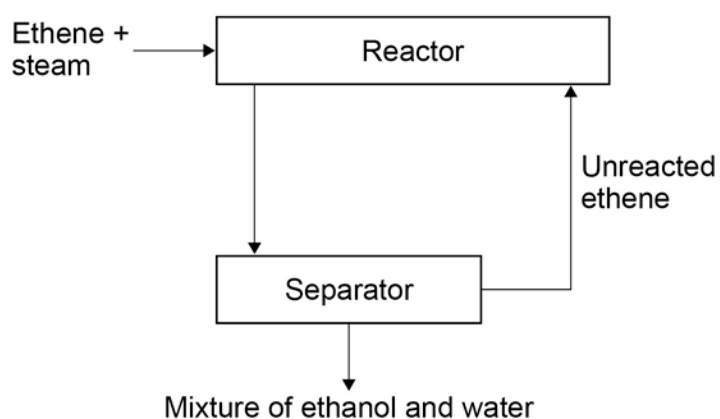
In industry ethanol is produced by the reaction of ethene and steam at 300°C and 60 atmospheres pressure using a catalyst.

The equation for the reaction is:



Figure 12 shows a flow diagram of the process.

Figure 12

**1 0**. **1**

Why does the mixture from the separator contain ethanol and water?

[1 mark]

1 0 . **2** The forward reaction is exothermic.

Use Le Chatelier's Principle to predict the effect of increasing temperature on the amount of ethanol produced at equilibrium.

Give a reason for your prediction.

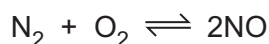
[2 marks]

1 0 . **3** Explain how increasing the pressure of the reactants will affect the amount of ethanol produced at equilibrium.

[2 marks]

END OF QUESTIONS

- 7 This is an equation for a reaction that occurs in a lightning flash.



Very high temperatures are needed.

- (a) (i) Explain how you can tell that this equation refers to an equilibrium.

..... [1]

- (ii) Use ideas about rates to explain what is happening when the reaction reaches dynamic equilibrium.

.....

..... [2]

- (b) Scientists can use this reaction to make nitrogen compounds from gases in the air.

- (i) Suggest a use for these compounds.

.....

..... [1]

- (ii) The scientists discuss increasing the pressure on the reaction.

Describe and explain the effect on the equilibrium position.

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..... [2]

- (c) There are several ways of making nitrogen compounds from nitrogen gas in industry.

Give **two** reasons why scientists may choose this reaction and **one** against.

Reason for

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Reason for

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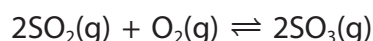
Reason against

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[3]

7 The industrial production of sulfuric acid involves several steps.

One of these steps is the reaction of sulfur dioxide, SO_2 , with oxygen to form sulfur trioxide, SO_3 .



- (a) What volume of sulfur trioxide, in dm^3 , is produced by the complete reaction of 750 dm^3 of sulfur dioxide?
(all volumes of gases are measured under the same conditions of temperature and pressure) (1)

- A 375.5
 B 750
 C 1125.5
 D 1500

- (b) Calculate the volume of oxygen needed to react completely with 750 dm^3 of sulfur dioxide.
(all volumes of gases are measured under the same conditions of temperature and pressure) (1)

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volume of oxygen = dm^3

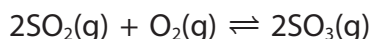
- (c) Calculate the mass, in kilograms, of 750 dm^3 of sulfur dioxide, measured at room temperature and pressure.
(relative formula mass: $\text{SO}_2 = 64$;
1 mol of any gas at room temperature and pressure occupies 24 dm^3) (3)

.....

mass of sulfur dioxide = kg



*(d) The reaction to produce sulfur trioxide reaches an equilibrium.



The forward reaction is exothermic.

The rate of attainment of equilibrium and the equilibrium yield of sulfur trioxide are affected by pressure and temperature.

A manufacturer considered two sets of conditions, A and B, for this reaction.

In each case sulfur dioxide is mixed with excess oxygen.

The manufacturer changed the temperature and the pressure and only used a catalyst in B.

The sets of conditions A and B are shown in Figure 7.

set of conditions	pressure in atm	temperature in °C	catalyst
A	2	680	no catalyst used
B	4	425	catalyst used

Figure 7

The manufacturer chooses set of conditions B rather than set of conditions A.

Explain, by considering the effect of changing the conditions on the rate of attainment of equilibrium and on the equilibrium yield of sulfur trioxide, why the manufacturer chooses the set of conditions B rather than the set of conditions A.

(6)

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DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(Total for Question 7 = 11 marks)



P 5 2 4 7 6 A 0 1 7 2 8

Question 10

Question	Answers	Extra information	Mark	AO / Spec. Ref.
10.1	both water <u>vapour</u> and ethanol will condense	allow steam for water vapour allow they both become liquids allow ethane condenses at a lower temperature allow some of the steam hasn't reacted allow it is a reversible reaction/equilibrium	1	AO3/2a 4.1.1.2 4.2.2.4 4.7.2.2
10.2	amount will decrease because the equilibrium will move to the left		1 1	AO1/1 AO2/1 4.6.2.1, 2, 4, 6 4.7.2.2
10.3	more ethanol will be produced because system moves to least/fewer molecules		1 1	AO2/1 4.6.2.1, 2, 3, 6 4.7.2.2
Total			5	

Question			Answer	Marks	AO element	Guidance
7	(a)	(i)	Equilibrium sign / \rightleftharpoons / arrows point both ways ✓	1	1.1	ALLOW answers referring to the sign/arrow IGNORE it is reversible
		(ii)	forward and back(ward) reactions / both directions / reactants(N ₂ and O ₂) forming products (NO) <u>and</u> products forming reactants ✓ rates are equal ✓	2	2 × 1.1	ALLOW equations for the correct reactions
	(b)	(i)	Fertilisers / explosives	1	1.1	ALLOW for growth of/nitrates for plants but IGNORE plants alone/ammonia/Haber process
		(ii)	No change ✓ Equal moles/molecules/particles on each side (of the equation) ✓	2	2 × 1.1	Mark separately
	(c)		Any two FOR: 100% atom economy / all reactants used up idea ✓ No by-products / no waste ✓ raw materials come from the air ✓ sustainable ✓ works at low pressure / AW ✓ Any one AGAINST: (very) high temperature (needed) / needs a lot of energy/fuel / doesn't give 100% yield / low yield ✓	3	3 × 2.1	ALLOW 'high atom economy' IGNORE 'readily available' IGNORE 'renewable'

Question Number	Answer	Mark
7(a)	<p>B 750</p> <p>The only correct answer is B</p> <p><i>A is not correct because 375.5 dm³ is half the actual volume formed</i></p> <p><i>C is not correct because 1125.5 dm³ is one and a half times the actual volume formed</i></p> <p><i>D is not correct because 1500 dm³ is double the actual volume formed</i></p>	<p>(1)</p> <p>AO 2 1</p>

Question Number	Answer	Additional guidance	Mark
7(b)	$\frac{1}{2} \times 750$ (1) = 375 (dm ³)	375 alone (1)	<p>(1)</p> <p>AO 2 1</p>

Question Number	Answer	Additional guidance	Mark
7(c)	<p>final answer of 2 (kg) with or without working (3)</p> <p>OR</p> <p>moles of SO₂ = $\frac{750}{64}$ (1) (= 31.25)</p> <p>mass of SO₂ = $\frac{24}{64} \times 750$ (1)</p> <p>(= 2000)</p> <p>mass of SO₂ = $\frac{2000}{1000}$ (1)</p> <p>(= 2 (kg))</p>	<p>allow ECF throughout</p> <p>31.25 x 64 (2) allow ECF</p> <p>allow any calculated mass / 1000 (1)</p> <p>final answer 2000 (kg) (2)</p>	<p>(3)</p> <p>AO 2 1</p>

Question Number	Indicative content	Mark
7(d)	<p>Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlines in the generic mark scheme.</p> <p>The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant.</p> <ul style="list-style-type: none"> • equilibrium reached faster because of higher temperature in set A / equilibrium reached slower because of lower temperature in set B • higher temperature means more frequent collisions because molecules have more energy / ORA for lower temperature in set B • decrease in temperature increases equilibrium yield but system takes longer to reach equilibrium • temperature chosen for optimum conditions • yield lower as forward reaction is exothermic • high temperature favours back reaction which is endothermic • equilibrium reached faster because of higher pressure in set B / equilibrium reached slower because of lower pressure in set A • higher pressure causes molecules to be closer together so more frequent collisions / ORA for lower pressure in set A • yield higher because products occupy smaller volume than reactants for set B • catalyst in set B causes equilibrium to be reached faster • catalyst increases rate of both forward and back reactions • equilibrium position not affected so catalyst does not affect yield • catalyst reduces the need for the higher temperature 	<p>(6)</p> <p>AO 2 1 AO 3 1a AO 3 1b</p>
Level	Mark	Descriptor
	0	No rewardable material.
Level 1	1–2	<ul style="list-style-type: none"> • Interpretation and evaluation of the information attempted but will be limited with a focus on mainly just one variable. Demonstrates limited synthesis of understanding. (AO3) • The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3–4	<ul style="list-style-type: none"> • Interpretation and evaluation of the information on both variables, synthesising mostly relevant understanding. (AO3) • The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5–6	<ul style="list-style-type: none"> • Interpretation and evaluation of the information, demonstrating throughout the skills of synthesising relevant understanding. (AO3) • The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)

Total for question 7 = 11 marks