1 There are many compounds that contain carbon and hydrogen only.

(a) Pentane has the formula $CH_3(CH_2)_3CH_3$.

Calculate the molar mass of pentane.

The relative atomic mass, A_r, of H = 1 and of C = 12.

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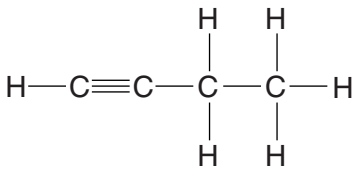
molar mass = ... g/mol **[1]**

(b) Look at the displayed formula for butyne.



What is the **molecular formula** for butyne?

..... **[1]**

(c) Look at the molecular formula of some compounds.

Which **two** compounds have the same **empirical** formula?

Choose from

CH_4	C_2H_2	C_2H_4
C_2H_6	C_3H_4	C_6H_6

answer ..... and ..... **[1]**

(d) David analyses a sample of a gas.

He finds it contains 1.2 g of carbon and 0.4 g of hydrogen.

Calculate the empirical formula for this gas.

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empirical formula is ..... **[2]**

[Total: 5]

2 Carbon dioxide, CO_2, reacts with hydrogen, H_2, to make methanol, CH_3OH.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O\ (g)$$

Phil investigates this reversible reaction.

He mixes carbon dioxide with hydrogen.

He lets this mixture reach equilibrium.

Phil measures the percentage yield of methanol in this equilibrium mixture.

He uses different temperatures and pressures.

Look at his results.

Pressure in atmospheres	**Temperature in °C**			
	100	200	300	400
20	90%	81%	52%	38%
40	93%	87%	70%	58%
60	96%	92%	83%	73%
80	98%	95%	90%	83%
100	99%	97%	94%	90%

(a) The percentage yield and position of equilibrium change with temperature, pressure and concentration of carbon dioxide.

Describe how the percentage yield of methanol changes with temperature and with pressure.

Describe how, and explain why, the position of equilibrium changes as extra carbon dioxide is added to the equilibrium mixture.

The quality of written communication will be assessed in your answer to this question.

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..... **[6]**

(b) Phil works as part of a team of research chemists.

It is a good idea for scientists to work as part of a team when solving scientific problems.

Explain why.

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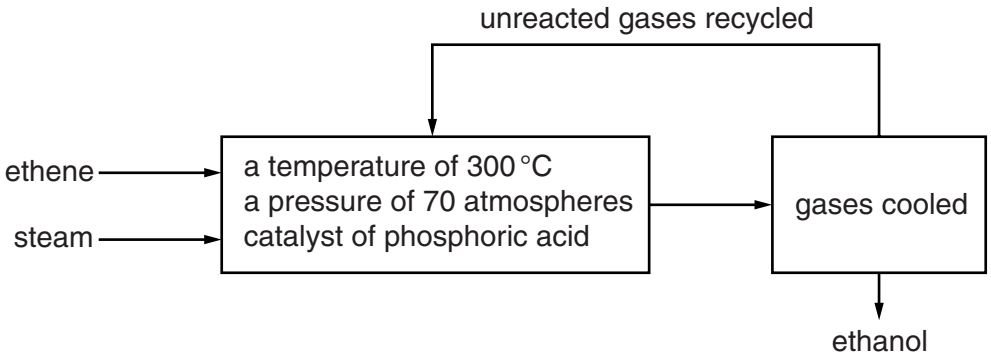
..... **[2]**

[Total: 8]

3 Ethanol (alcohol) is made by reacting ethene with steam.

$$\text{ethene} + \text{steam} \rightleftharpoons \text{ethanol}$$

Look at the flowchart.



Look at the table.

It gives some information about the percentage yield of ethanol at different temperatures and pressures.

Pressure in atmospheres	**Percentage yield**		
	200 °C	**300 °C**	**400 °C**
40	16	12	6
80	30	22	12
120	42	30	17
160	50	36	21

(a) (i) What happens to the percentage yield as the **pressure** increases?

..... **[1]**

(ii) What happens to the percentage yield as the **temperature** increases?

..... **[1]**

(b) The highest percentage yield is achieved with a temperature of 200 °C and 160 atmospheres.

The actual conditions used to make ethanol are:

- catalyst of phosphoric(V) acid
- a pressure of 70 atmospheres
- a temperature of 300 °C.

Use ideas about percentage yield and rate of reaction to suggest why each condition is used.

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..... **[3]**

(c) This process is automated.

Explain why automation is used.

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..... **[1]**

[Total: 6]

4 Stowmarket Synthetics manufacture ethanoic acid, $C_2H_4O_2$, by two different processes.

Process **1** $C_2H_6O + O_2 \rightarrow C_2H_4O_2 + H_2O$

Process **2** $CH_4O + CO \rightarrow C_2H_4O_2$

Look at the table of relative formula masses.

Compound	Formula	Relative formula mass, M_r
ethanol	C_2H_6O	46
oxygen	O_2	32
ethanoic acid	$C_2H_4O_2$	60
water	H_2O	18
methanol	CH_4O	32
carbon monoxide	CO	28

The relative atomic mass of H = 1, of C = 12, and of O = 16.

(a) In process **2**, Stowmarket Synthetics use 320 g of methanol.

Calculate the maximum mass of ethanoic acid that can be made.

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..... **[2]**

(b) Stowmarket Synthetics know that the **atom economy** of a process is important.

Water is a waste product in process **1**.

Show that the atom economy for making ethanoic acid by process **1** is 77%.

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..... **[2]**

(c) Stowmarket Synthetics also know that the **percentage yield** of a process is important.

The factory uses 5.2 tonnes of methanol in process **2**.

A scientist predicts they should make 9.8 tonnes of ethanoic acid.

They actually make 9.5 tonnes of ethanoic acid.

Show that the percentage yield of ethanoic acid is 97%.

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..... **[2]**

(d) Look at the table.

It gives information about the atom economy and percentage yield for making ethanoic acid.

Process	Atom economy (%)	Percentage yield (%)
1	77	85
2	100	97

Process **2** has a higher atom economy and a higher percentage yield.

(i) Explain one advantage, other than cost, of a very high atom economy.

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..... **[1]**

(ii) Explain one advantage, other than cost, of a very high percentage yield.

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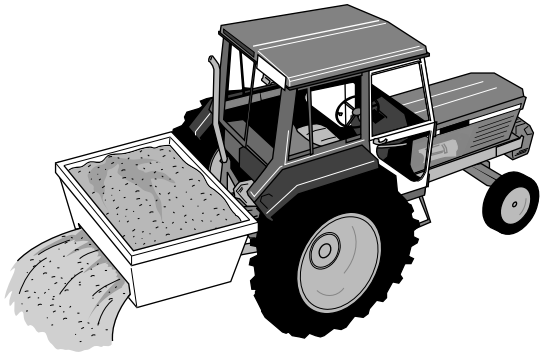
..... **[1]**

[Total: 8]

5 This question is about fertilisers.



Farmers use fertilisers to make crops grow bigger and faster. This increases crop yield.

(a) Explain how the use of fertilisers increases crop yield.

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..... **[2]**

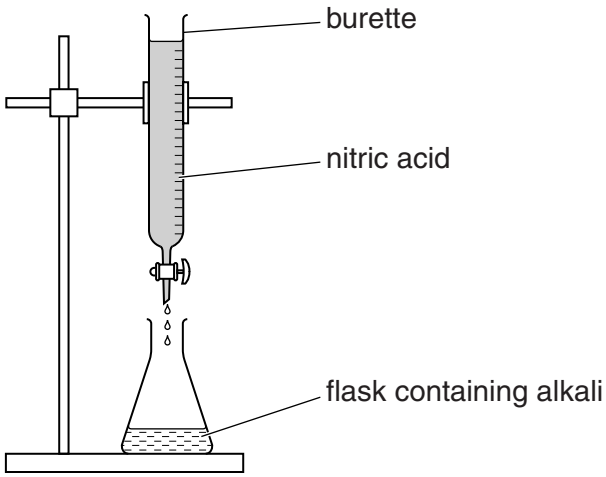
(b) Ammonium phosphate, $(NH_4)_3PO_4$, is used as a fertiliser.

Write down the total number of **atoms** in the formula $(NH_4)_3PO_4$.

answer ..... **[1]**

(c) Chloe makes some potassium nitrate by neutralising an alkali with nitric acid.

Look at the diagram. It shows the apparatus she uses.



(i) Write down the **name** of the **alkali** Chloe uses to make potassium nitrate.

..... **[1]**

(ii) Chloe adds nitric acid to the flask until the solution is **neutral**.

Explain, using the ions involved, why the alkali is neutralised by nitric acid.

.....

..... **[1]**

[Total: 5]

6 This question is about industrial processes.

(a) An industrial process makes sulfur trioxide.

Sulfur dioxide, SO_2, reacts with oxygen, O_2.

Sulfur trioxide, SO_3, is made.

Write the **balanced symbol** equation for this reaction.

..... **[2]**

(b) A second industrial process makes an acid.

Look at the table. It shows the percentage yield of the acid made at different temperatures and pressures.

pressure in atmospheres	percentage yield at 200 °C	percentage yield at 400 °C	percentage yield at 600 °C
100	80%	22%	8%
200	92%	40%	14%
300	95%	56%	18%
400	96%	67%	22%

(i) How does **increasing** the **temperature** change the percentage yield?

..... **[1]**

(ii) A temperature of 400 °C, a pressure of 200 atmospheres and a catalyst are used to make the acid.

These conditions do not give the highest percentage yield.

Suggest why these conditions are chosen.

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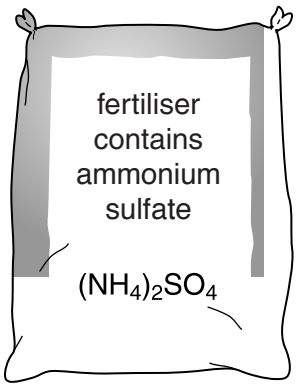
..... **[3]**

[Total: 6]

7 Fertilisers and medicines are useful chemicals.

Ammonium sulfate is used as a fertiliser.



Ammonium sulfate is made by reacting ammonia with dilute sulfuric acid.

The ammonia needed for this reaction is made in a **continuous** process.

This is different to the **batch** process used to make most medicines.

(a) (i) A continuous process is used to make ammonia but a batch process is used to make most medicines.

Explain why.

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..... **[2]**

(ii) It is more expensive to make medicines than it is to make ammonium sulfate fertiliser.

Suggest why.

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..... **[1]**

(b) Alex makes some ammonium sulfate in a laboratory.

(i) Alex predicts he should make 8.0 g of ammonium sulfate.

He actually makes 6.0 g.

Show, by calculation, that his **percentage yield** of ammonium sulfate is 75%.

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..... **[2]**

(ii) The companies who make ammonium sulfate fertiliser on an industrial scale want as high a percentage yield as possible.

Explain why.

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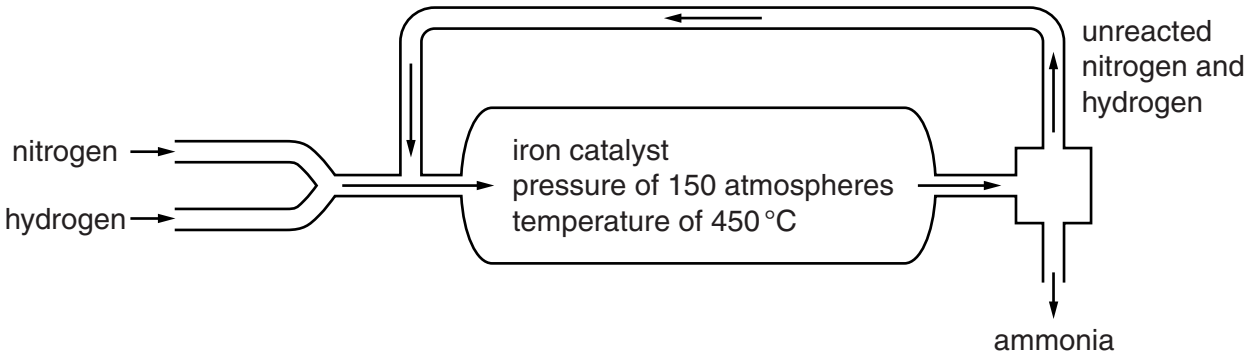
..... **[2]**

[Total: 7]

8 Look at the diagram. It shows how ammonia is made in the Haber process.



(a) Write a **word** equation for the process.

..... **[1]**

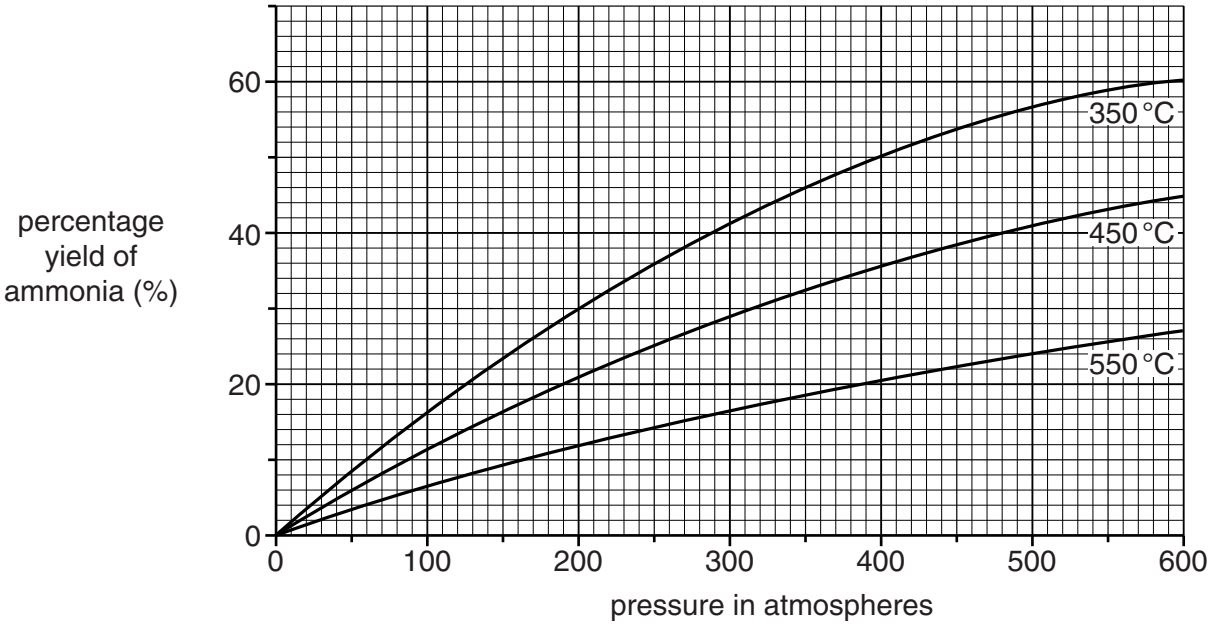
(b) The reaction is **reversible**.

What symbol is used to represent a reversible reaction?

..... **[1]**

(c) Look at the graph.

It shows the percentage yield of ammonia at different temperatures and pressures.



What is the percentage yield of ammonia at **350 °C** and **200 atmospheres**?

answer .....% **[1]**

(d) Look at the graph.

(i) What conditions, shown on the graph, give the **highest** yield of ammonia?

pressure = ... atmospheres

temperature = ... °C **[1]**

(ii) It is too expensive to use these conditions to make ammonia.

Suggest why.

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..... **[2]**

(e) Ammonia is used to make ammonium nitrate, NH_4NO_3.

Ammonium nitrate is a fertiliser.

What is the number of **different elements** in the formula, NH_4NO_3?

..... **[1]**

[Total: 7]

9 Hydrogen peroxide has the molecular formula H_2O_2.

Hydrogen peroxide can be manufactured by reacting barium peroxide, BaO_2, with sulfuric acid, H_2SO_4.

$$BaO_2 + H_2SO_4 \longrightarrow BaSO_4 + H_2O_2$$

Barium sulfate, $BaSO_4$, is a waste product.

Look at the table of relative formula masses, M_r.

formula	relative formula mass, M_r
BaO_2	169
H_2SO_4	98
$BaSO_4$	233
H_2O_2	34

(a) Show that the **atom economy** for the reaction is 12.7%.

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..... **[1]**

(b) A factory makes 18 tonnes of hydrogen peroxide.

Phil predicts the factory should make 20 tonnes of hydrogen peroxide.

Calculate the **percentage yield** of hydrogen peroxide.

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percentage yield = ... % **[2]**

(c) The manufacture of hydrogen peroxide from barium peroxide is **not sustainable**.

Explain why.

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..... **[1]**

[Total: 4]