1 Fertilisers are used to promote plant growth.
Two fertilisers are ammonium phosphate, $(NH_4)_3PO_4$, and calcium dihydrogenphosphate, $Ca(H_2PO_4)_2$.

(a) Describe a test to distinguish between these two fertilisers.

test .....

..... [2]

result .....

..... [1]

(b) Many fertilisers are manufactured from ammonia. Describe how ammonia is made in the Haber process. Give the essential conditions and an equation for the process.

.....

.....

.....

..... [4]

(c) State the essential plant nutrient not supplied by ammonium phosphate.

..... [1]

(d) The soluble compound, calcium dihydrogenphosphate is made by heating the insoluble mineral rock phosphate, $Ca_3(PO_4)_2$, with sulfuric acid.

(i) Why would rock phosphate not be effective as a fertiliser?

..... [1]

(ii) The phosphate ion, PO_4^{3-}, from the rock phosphate is changed into the dihydrogenphosphate ion, $H_2PO_4^-$.

$$PO_4^{3-} + 2H_2SO_4 \rightarrow H_2PO_4^- + 2HSO_4^-$$

What type of reagent is the phosphate ion? Give a reason for your choice.

.....

..... [2]

(e) The extensive use of fertilisers and possibly the effect of acid rain tend to increase the acidity of the soil. State why it is necessary to control soil acidity and explain how this can be done.

.....

..... [2]

[Total: 13]

2 Ammonia is an important industrial chemical.

(a) (i) Give the electron structure of an atom of nitrogen.

..... [1]

(ii) Use this electronic structure, rather than the valency of nitrogen, to explain why the formula of ammonia is NH_3 not NH_4.

.....

.....

..... [2]

(b) Ammonia is made by the Haber Process.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ forward reaction is exothermic

The percentage of ammonia in the equilibrium mixture varies with conditions.

pressure / atmospheres	100	200	300	400
% ammonia at 300 °C	45	65	72	78
% ammonia at 500 °C	9	18	25	31

The conditions actually used are 200 atmospheres, 450 °C and an iron catalyst.

(i) The original catalyst was platinum. Suggest a reason why it was changed to iron.

..... [1]

(ii) Explain why the highest pressure gives the highest percentage of ammonia in the equilibrium mixture.

.....

..... [2]

(iii) What happens to the unreacted nitrogen and hydrogen?

.....

..... [1]

(iv) State **one** advantage and **one** disadvantage of using a lower temperature.

advantage .....

..... [1]

disadvantage .....

..... [1]

[Total: 9]

3 Ammonia is manufactured by the Haber process.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ the forward reaction is exothermic

(a) Name the raw materials from which nitrogen and hydrogen are obtained.

nitrogen from ..... [1]

hydrogen from ..... [1]

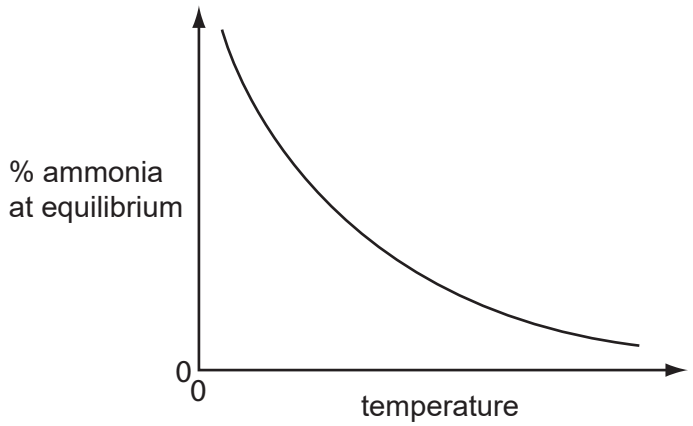
(ii) Name the catalyst used in this process.

..... [1]

(iii) What is the most important use of ammonia?

..... [1]

(b) The following graph shows how the percentage of ammonia in the equilibrium mixture changes with temperature.



(i) Explain the term *equilibrium*.

.....

.....

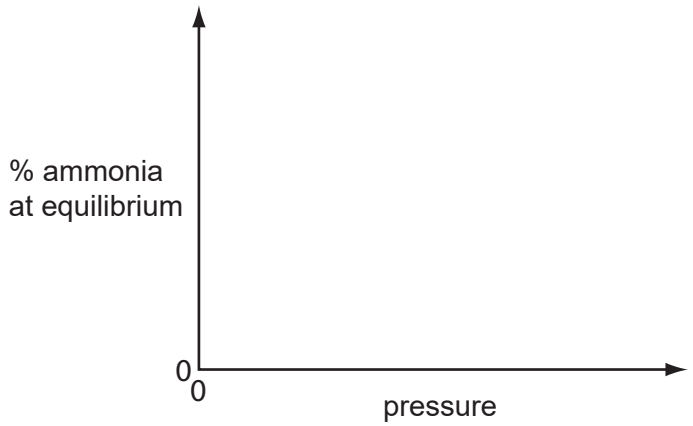
.....

..... [2]

(ii) How does the percentage of ammonia vary with temperature?

..... [1]

(c) (i) Sketch a graph which shows how the percentage of ammonia in the equilibrium mixture varies with pressure.



[1]

(ii) Explain why the graph has the shape shown.

.....

.....

..... [2]

[Total: 10]

4 Ammonia is manufactured by the Haber Process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$
200 atmospheres
450°C

The forward reaction is exothermic.

(a) (i) What is the catalyst for this reaction?

.....

[1]

(ii) Newer catalysts have been discovered for this process. Using these catalysts, the operating temperature is lowered from 450°C to 400°C. What is the advantage of using a lower temperature?
Explain your answer.

advantage .....

explanation .....

.....

[2]

(b) After passing over the catalyst, the mixture contains 15% of ammonia. It is cooled and the ammonia liquefies and is separated from the unreacted nitrogen and hydrogen. They are recycled.

(i) How are the gases recycled?

.....

[1]

(ii) Only ammonia gas liquefies. Suggest an explanation for this.

.....

[1]

(c) Urea, $CO(NH_2)_2$, is one of the fertilisers manufactured from ammonia.
Ammonia is heated with carbon dioxide.

(i) Write an equation for the manufacture of urea.

.....

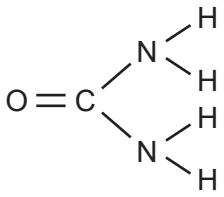
[2]

(ii) Explain why urea on its own might not be very effective in promoting crop growth.

.....

[1]

(d) Give a diagram showing the arrangement of the valency electrons in one molecule of the covalent compound urea. Its structural formula is given below.



Use o to represent an electron from a carbon atom.
Use x to represent an electron from a hydrogen atom.
Use • to represent an electron from a nitrogen atom.

[3]

5 In 1909, Haber discovered that nitrogen and hydrogen would react to form ammonia. The yield of ammonia was 8%.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3$ (g) the forward reaction is exother

catalyst platinum
temperature 600 °C
pressure 200 atm

(a) Describe how hydrogen is obtained for the modern process.

.....

..... [2]

(b) What is the catalyst in the modern process?

..... [1]

(ii) Explain why the modern process, which uses a lower temperature, has a higher yield of 15%.

.....

..... [2]

(c) Complete the following table that describes the bond breaking and forming in the reaction between nitrogen and hydrogen to form ammonia.

bonds	energy change /kJ	exothermic or endothermic
1 mole of N ≡ N broken	+94	.....
3 moles of ..... broken	+130	.....
6 moles of N – H formed	-232	.....

[3]

(ii) Explain, using the above data, why the forward reaction is exothermic.

.....

..... [2]

6 An organic compound decomposes to form nitrogen.

$C_6H_5N_2Cl(aq) \rightarrow C_6H_5Cl(l) + {}_2(g)$

(a) Explain the state symbols.

aq .....

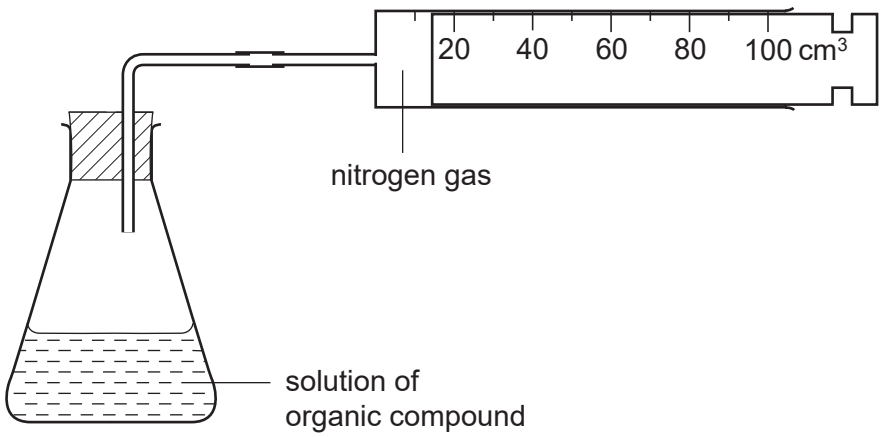
l .....

g ..... [2]

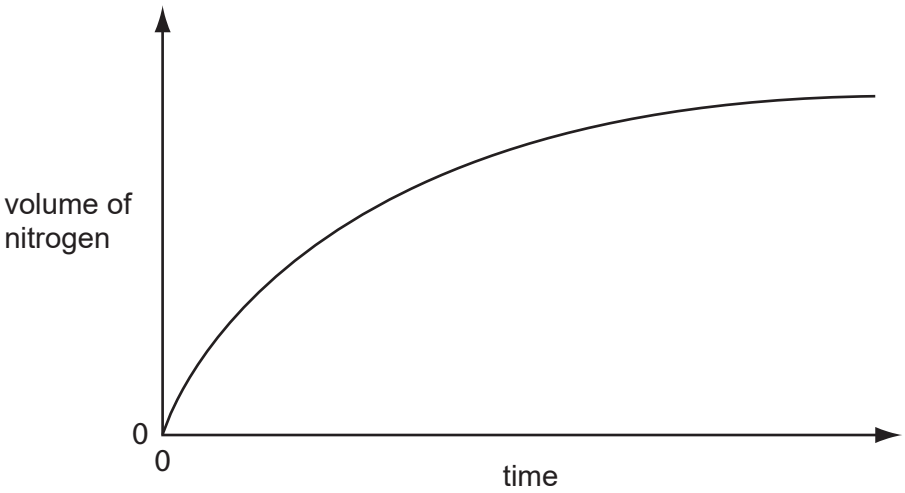
(b) Draw a diagram to show the arrangement of the valency electrons in **one** molecule of nitrogen.

[2]

(c) The rate of this reaction can be measured using the following apparatus.



The results of this experiment are shown on the graph below.



(i) How does the rate of this reaction vary with time?

.....

..... [1]

(ii) Why does the rate vary?

.....

..... [2]

(iii) The reaction is catalysed by copper powder. Sketch the graph for the catalysed reaction on the same grid. [2]

(iv) Why is copper powder more effective as a catalyst than a single piece of copper?

..... [1]