All questions are for separate science students only

Q1.

This question is about fertilisers.

Compounds of nitrogen (N), phosphorus (P) and potassium (K) are used as fertilisers to improve agricultural productivity.

The table below shows information about three compounds, **A**, **B** and **C**, that can be used as fertilisers.

	Compound A	**Compound B**	**Compound C**
Name	potassium chloride	ammonium nitrate	diammonium hydrogen phosphate
Formula	KCl	NH_4NO_3	$(NH_4)_2HPO_4$
Percentage (%) of N, P and K by mass	**K**: 52%	**N**: 35%	**N**: 21% **P**: 23%
Cost in £/kg	0.24	0.23	0.35

(a) A scientist analysed the percentages of nitrogen, phosphorus and potassium in a soil.

The percentages of nitrogen and of potassium in the soil were lower than the percentages needed for high agricultural productivity.

There was sufficient phosphorus in the soil for high agricultural productivity.

Evaluate the use of the compounds in the table above to improve the agricultural productivity of this soil. **(chemistry only)**

A: KCl - Only contains K
- Only source of K so is needed.

B: NH_4NO_3 - Only contains N
- Contains more N than (C), so preferable and is cheaper than (C)

C: $(NH_4)_2HPO_4$ - Contains P which is not needed

Have contain K & N, so mixture needed

A + B should be used

(A + C could be used)

(4)

(b) How is potassium chloride (compound **A**) obtained from the Earth? **(chemistry only)**

Mining (quarrying)

(1)

(c) Name **one** other compound that could be used instead of potassium chloride (compound **A**) to give a similar improvement in agricultural productivity. **(chemistry only)**

Potassium sulfate K_2SO_4

(1)

(d) Nitric acid is needed to produce ammonium nitrate (compound **B**).

Name a compound needed to produce nitric acid. **(chemistry only)**

Ammonia NH_3

(1)

(e) Phosphate rock contains phosphorus compounds.

Plants absorb phosphorus from compounds dissolved in rainwater.

Suggest why phosphate rock **cannot** be used directly as a fertiliser. **(chemistry only)**

Phosphate rock is insoluble in water

(1)

(f) Phosphate rock can be treated with different acids to produce salts useful as fertilisers.

Name the salts which are produced by treating phosphate rock with:

- sulfuric acid
- phosphoric acid. **(chemistry only)**

Sulfuric acid: Calcium sulfate $CaSO_4$

Phosphoric acid: Calcium phosphate $Ca_3(PO_4)_2$

(2)

(Total 10 marks)

Q2.

Ammonia is produced in the Haber process.

The raw materials for the Haber process are nitrogen and hydrogen.

The equation for the reaction is:

$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$$

(a) Give the sources of the nitrogen and of the hydrogen used in the Haber process. **(chemistry only)**

Nitrogen Air

Hydrogen Natural gas

(2)

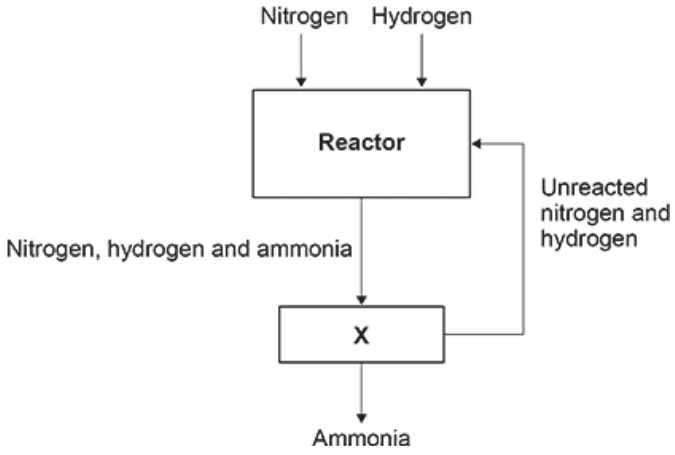
(b) How does the equation for the reaction show that the atom economy of the forward reaction is 100%? **(chemistry only)**

There is only one product

(1)

(c) **Figure 1** represents the Haber process.

Figure 1



Explain how the ammonia produced is separated from the unreacted nitrogen and hydrogen in **X**. **(chemistry only)**

The mixture is cooled, so ammonia liquefies

(2)

The Haber process uses a temperature of 450 °C and a pressure of 200 atmospheres.

The table below shows the percentage yield of ammonia produced at 450 °C using different pressures.

Pressure in atmospheres	Percentage (%) yield of ammonia
60	9
120	18
180	25
240	31
300	36
360	40
420	43

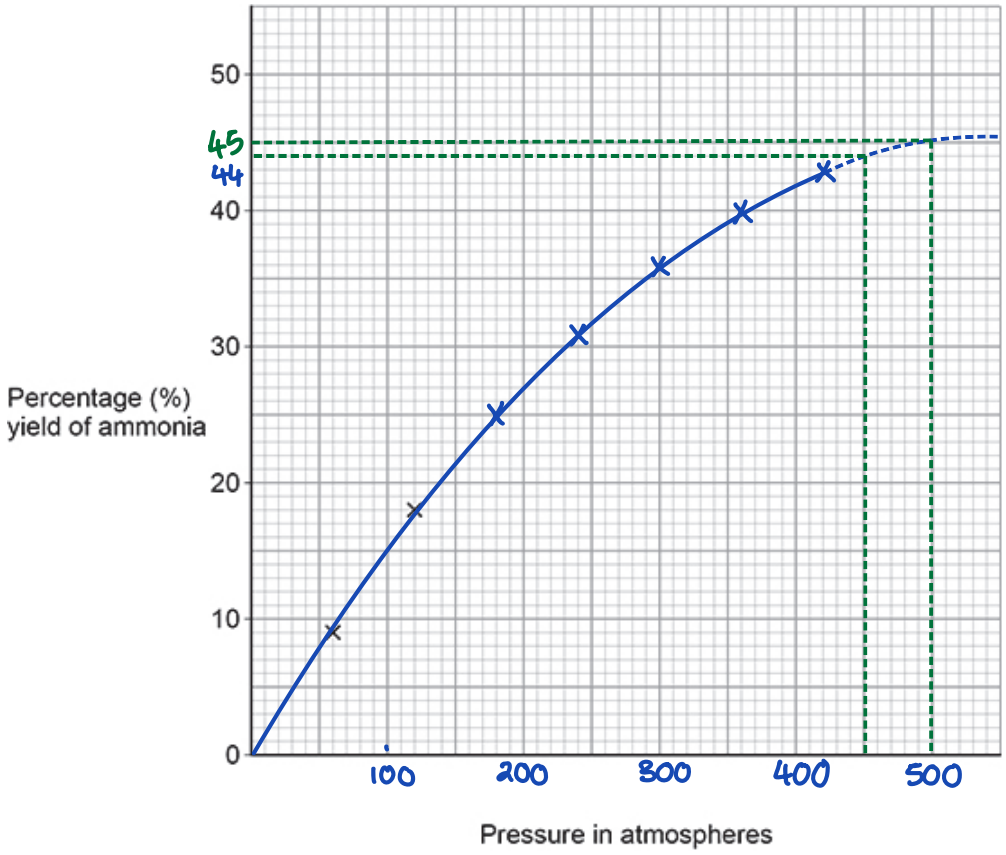
(d) Complete **Figure 2**. **(chemistry only)**

The first two points have been plotted.

You should:

- use a suitable scale for the *x*-axis
- plot the remaining data from the table above
- draw a line of best fit.

Figure 2



(4)

(e) Determine the percentage yield of ammonia at 450 °C and 500 atmospheres.
(chemistry only)

Show your working on **Figure 2**.

Percentage yield = 45 %

(2)

(f) The equation for the production of ammonia in the Haber process is:

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$$

The forward reaction is exothermic.

The conditions used are:

- a temperature of 450 °C
- a pressure of 200 atmospheres
- the presence of an iron catalyst.

Explain why these conditions are chosen for economical production of ammonia in the Haber process.

You should include references to the rate of reaction and the position of equilibrium.
(chemistry only) (HT only)

Rate: ↑T = ↑Rate · more frequent collisions
more particles with Activation Energy
↑P = ↑Rate · more frequent collisions
Catalyst = ↑Rate · ↓ Activation Energy

Equilibrium:
↑T shifts to LHS (exothermic)
↑P " " RHS (fewer molecules on RHS)
Catalyst · No effect

↑T - ↑ Energy and costs
↑P - ↑ Energy and costs
- Stronger materials needed

(6)

(Total 17 marks)

Catalyst reduces costs

Temp is a compromise between Rate & Eq^m
Cost

Pressure is a compromise between Yield, Rate & Cost.