AQA GCSE CHEMISTRY (HIGHER) · 8462

CHEMISTRY



MARK SCHEME

4.10.4 THE HABER PROCESS AND THE USE OF NPK FERTILISERS (PACK 2)

SCORE	PERCENTAGE
/136	%

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Q1.

Effect of pressure

- high pressure increases yield
  for 1 mark

- either because less product molecules (Le Chatelier)
  or but high pressure increases cost/safety
  for 1 mark

Effect of temperature

- low temperature increases yield
  for 1 mark

- either because exothermic reaction (Le Chatelier)
  for 1 mark

- or but at low temperature rate is slow/catalyst does not work

Compromise

- optimum conditions to balance rate and % yield
  for 1 mark

- or rate is slow (at higher temperature) so need a catalyst
  or low percentage conversion so recycle untreated gases

[5]

Q2.

(i) A = air
B = natural gas
for 1 mark each

2

(ii) nitrogen
both for 1 mark

1

(iii) catalyst / speed up reaction
for 1 mark

1

(iv) recycle unreacted gases / save money
for 1 mark

1

[5]

Q3.

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(a) (i) A = air
B = natural gas / methane / north sea gas / CH_4 / oil / naphtha/ steam water (H_2O)

Accept answers written in the box at the start of the question.

each for 1 mark

2

(ii) catalyst / speed up the reaction / lower the activation energy

for 1 mark

1

(b) (i) 3 2

for 1 mark

1

(ii) reversible reaction

so that amount of product depends on conditions used

(linked to first point)

best yield at low temperatures

because it is an exothermic reaction / gives out heat (linked)

reaction rate too slow at low temperatures

450 °C is a compromise between a reasonable yield of ammonia at a fast rate of reaction

catalyst works best when heated

best yield at high pressures

because there is a decrease in the number of gaseous molecules (linked)

increasing the pressure also increases the rate

the pressure used is limited by cost, safety etc

the fact that all the nitrogen and hydrogen are not converted to ammonia does not matter because unreacted gases can be recycled through process

any six for 1 mark each

6

[10]

Q4.

(a) plot correct (2 segments)

for 1 mark

1

(b) nitrogen + hydrogen $\rightleftharpoons$ ammonia
or N_2 H_2 NH_3

all correct for 1 mark

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1

(c) largest area labelled nitrogen or shaded

for 1 mark

1

(d) (i) nitrogen

1

oxygen

hydrogen

1

three correct for 2 marks
two correct for 1 mark

(ii) potassium chloride

for 1 mark

1

(e) (i) $NH_4NO_3 = 14 + (4 \times 1) + 14 + (3 \times 16) = 80$

for one mark

1

(ii) ecf (error carried forward from part (i))
look for 28 / 80 for first mark

gains 1 mark

but 35% (% sign not needed)

special case of (14 / 80 × 100 = 17.5%) gains 1 mark

gains 2 marks

2

[9]

Q5.

(a) (i) both scales (must be sensible) (use at least half the paper)
plots for 350°C (to accuracy of +/- 1/2 square)
plots for 500°C (to accuracy of +/- 1/2 square)
lines of best fit (sensible smooth curves) (ignore below 50 atm.)
(must not join the dots and each curve must be a single line)

for 1 mark each

4

(ii) read accurately from their graph (must be 350 °C and pressure read to +/– half square from their graph)

for one mark

1

(iii) smooth curve drawn between 350°C and 500 °C - must be of similar shape to the other curves - a dashed line would be accepted here but would not be accepted for part (i)

for one mark

1

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(b) (i) reversible reaction (owtte) / equilibrium / equilibria / reaction goes in both directions etc.

for one mark

1

(ii) maximum of 2 marks from each section up to a maximum total of 5

<u>effect of temperature (max. 2 marks)</u>
best yield at low temperature / poor yield at high temperature
reaction too slow at low temperature / fast at high temperature

<u>effect of pressure (max. 2 marks)</u>
high yield at high pressure (owtte) / low yield at low pressure
ideas to do with cost / safety factor of using higher pressures

<u>evaluation (max. 2 marks)</u>
formation of ammonia favoured at low temperature **because** reaction is exothermic formation of ammonia favoured at high pressure **because** more reactant molecules than product molecules
actual temperature and / or pressure used are a compromise between good yield and reasonable rate ammonia removed / unreacted nitrogen and hydrogen recycled so rate more important than yield catalyst used (not a wrongly named catalyst)

for 1 mark each

5

(c) (i) $NH_4NO_3 = 14 + (4 \times 1) + 14 + (3 \times 16) = 80$ (ignore units)

for one mark

1

(ii) ecf (error carried forward from part (i))
look for (28/80) for first mark

gains 1 mark

but 35% (% sign not needed)

special case of (14/80 × 100 = 17.5%) gains one mark

gains 2 marks

2

[15]

Q6.

(a)

*the answer yes **or** no does not gain a mark*

Yes – plants will grow faster

*do **not** accept grow better*

1

more food available, greater yield

1

OR

No – plants still grow without adding nitrates

*accept the idea that **small** amounts of nitrate could be used*

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1

(nitrates) can 'kill' babies / causes brain damage

do not accept can stop respiration in babies

1

(b) (i) 2

accept two

1

(ii) $2 \times 14 + 4 \times 1 + 3 \times 16$

1

$= 80$

1

$\frac{28}{80} \times 100 = 35$ %

1

allow 1 mark for correct working for percentage 28/Y × 100, where Y is an incorrect formula mass
allow 2 marks for formula mass of 80 where no working ***or*** *correct working is shown*
allow 3 marks for 35 where no working ***or*** *correct working is shown*

[6]

Q7.

(a) as a catalyst

accept to speed up the reaction (equilibrium)

1

(b) nitrogen + hydrogen ⇌ ammonia

$N_2 + H_2 \rightleftharpoons NH_3$

accept mixed formula / word equations
ignore balancing

1

(c) (i) the reaction is reversible / an equilibrium

accept that ammonia can break down again into nitrogen and hydrogen
accept reaction goes both ways
do ***not*** *accept some nitrogen and hydrogen do not react*

1

(ii) (the gases are cooled)

no marks as given in the diagram
accept correct formulae NH_3, N_2 H_2

1

ammonia removed as a liquid

accept ammonia liquefies ***or*** *condenses*

nitrogen and hydrogen are recycled

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accept <u>nitrogen</u> and <u>hydrogen</u> are put back through the converter
accept 'other gases' only if ammonia identified for first mark

1

[5]

Q8.

(a) increases % / amount of ammonia

1

favours the forward reaction

1

(b) reaction(s) would be too slow

1

(c) any **three** from:

- rate increased
- decreases % / amount of ammonia
- the forward reaction is exothermic
- the backward reaction is endothermic
- backward reaction favoured / forward reaction not favoured
- yield / amount of nitrogen and hydrogen increased
- the relative amount (yield) of ammonia decreases as the <u>equilibrium</u> is changed
- the relative amount (yield) of nitrogen and hydrogen increases as the <u>equilibrium</u> is changed

explanations in terms of particles are neutral

3

[6]

Q9.

(a) ammonium nitrate

accept NH_4NO_3
*do **not** accept ammonia nitrate*

1

(b) different reactions need different catalysts

1

(c) they are used over and over again

accept they are reused
accept they are not used up
accept they are not changed
recycling is neutral

1

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(d) any **two** from

they speed up reactions

they reduce energy requirements

accept allow reactions to take place at a lower temperature

they reduce costs

accept make process more economic

2

(e) (high pressure) increases the frequency of collisions

accept more collisions
move faster is neutral

1

this increases the rate of reaction

accept 'more successful collisions' for 2 marks

1

[7]

Q10.

(a) (i) gas

accept they are all gases

1

(ii) reversible (reaction)

accept can go either way
accept ammonia can be decomposed (to nitrogen and hydrogen)
accept could be (an) equilibrium
do not credit just 'equilibrium'

1

(iii) (liquid) air **or** atmosphere

1

(iv) same number **or** amount **or** weight (of atoms) on each side (of the equation)

accept "sums" for each side

accept same amounts of elements on each side
*do not credit molecules **or** compounds*
do not credit both sides are the same unless explained

1

of the same type

***or** gives a correct example 'e.g. six hydrogen atoms' (on each side)*

1

(b) (i) nitrate **or** sulphate **or** phosphate

if first left blank, second may be awarded

do not credit chloride

nitric **or** sulphuric **or** phosphoric

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1

(only if correct above, exception is for ammonium chloride followed by hydrochloric acid (1 mark))

as appropriate if only the formula is given this should be credited only if it is correct in every detail i.e. NH_4NO_3 HNO_3 $(NH_4)_2SO_4$ H_2SO_4
accept correct name with an incorrect version of the formula
do not credit a correct formula with an incorrect version of the name e.g. 'nitrate/sulphite' etc

1

any **one** of

* (solution) can be sprayed (on the fields **or** crops)
accept more even distribution

* dissolves in soil water **or** rain (water)
accept soaks into soil (because soaks implies water)

* can be taken up by (plant) roots
do not credit can be added to water to "feed" the plants

1

(c) (i) elements **or** different atoms are bonded or joined **or** combined **or** reacted

do not credit just 'atoms'
*do not credit added **or** mixed*

1

(ii) (pairs of) electrons are shared

do not credit an electron is shared

1

[10]

Q11.

(a) (i) atmosphere

or (fractional distillation of liquid) air

1

(ii) **either**
more (chance) of them colliding/

not just 'faster'

coming into contact
or
the volume of the product / the ammonia is less than /
only half the volume of the reactants / the nitrogen and hydrogen

1

(iii) 3 × (1 ×2) of hydrogen
→ 2 × (14 +1 ×3) of ammonia

*accept 6 parts of hydrogen →34 parts of ammonia **or** similar*

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i.e. candidate uses the atomic masses and works correctly from the equation

1

= 225 (tonnes/t)

unit not required

1

(b) (i) megapascal(s)

accept million pascal(s)

1

(ii) 28 (%)

accept any answer in the range 28.0 to 28.5 inclusive

1

(iii) reduce the temperature and increase the pressure

both required

1

(iv) **either**

use a catalyst

accept use iron as a catalyst

accept use iron which has been more finely divided

accept use iron / catalyst with a bigger (surface) area

accept use a better catalyst

1

or

remove the ammonia (as it is produced)

*accept react the ammonia with **or** dissolve the ammonia in water (as it is produced)*

1

(c) ammonia
nitric acid
phosphoric acid

all three on the left correct

ammonia potassium chloride

all three on the right correct

water **or** water vapour

accept 'steam'

1

[10]

Q12.

(a) (i) 8

ammonia

do not credit ammonium

sulphuric acid

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do not credit just sulphuric; credit sulfuric acid
do not credit hydrogen sulphate

3

(ii) (as a) fertiliser

1

(iii) nitric (acid)
accept HNO_3 if correct in every detail

1

(b) (i) chemical change (in which)
or *under suitable conditions*

1

product(s) can be converted to reactant(s)
or *direction of reaction can be reversed*
or *equilibrium can be achieved*
do not credit reaction can be reversed

1

(ii) air
or *(the) atmosphere*

1

(iii) made of atoms

1

which are all the same
credit the idea that the particles (in an element) are all the same even if the name of the particles (the first mark) is incorrect
or *which have the same number of protons*
or *which have the same atomic number / proton number*
it cannot be broken down into anything simpler (2) marks

1

[10]

Q13.

(a) any **one** from

(as a) catalyst
or *to mix with promoters*

to speed up the reaction (process)
or *process is quicker do not credit just it is quicker*

to save energy
to reduce costs
or *process is cheaper*
do not credit just it is cheaper

larger surface area
(than lumps of iron)

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or *larger surface area for the (catalysed) reaction (to take place)*

1

(b) (i) water **or** steam
and methane
or natural gas
or North Sea gas

both required either order

1

(ii) **EITHER**
more (chance) of them colliding / coming into contact

do not credit just faster

OR volume of the product / ammonia less than / only half the volume of the reactants / the nitrogen and hydrogen

1

(iii) **EITHER**
680 (tonnes)

OR 28 (of nitrogen) → 34 (of ammonia)

accept any correct 14 : 17 ratio

1

560 (of nitrogen) → 34 × 20 (of ammonia)

3

[6]

Q14.

(a) N_2 + **3** H_2 ↔ **2** NH_3

2

(b) (i) lower temperature gives higher % conversion
higher pressure gives higher % conversion

each for 1 mark

2

(for T = 350 °C and P = 400 At. award 2 marks)

the most economical combination
reaction too slow at lower temperatures
plant too expensive at higher pressures

any 2 for 1 mark each

2

[6]

Q15.

(a) rate of reaction is increased
iron/powder
acts as catalyst
at higher temperatures
at higher pressures

any 4 answers for 1 mark each

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4

(b) yield of ammonia is increased at higher pressure
since equilibrium is moved to the right (idea)
but there is high cost in manufacturing the plant to withstand very high pressures
so optimum* pressure of about 250 atmospheres is used
(– just quoting the figures not enough)*
very high pressure increases safety risk
yield of ammonia is increased at lower temperatures
since equilibrium is moved to the right
but the rate of reaction is reduced at lower temperatures
so process becomes uneconomic
optimum temperature of about 450°C is used
yield of ammonia is increased if the ammonia is removed from the reaction mixture

since equilibrium is moved to the right (idea)
so ammonia is removed as a liquid after cooling and condensing
unreacted nitrogen and hydrogen recycled

(credit nitrogen and ammonia because of misprint on the diagram)

NB Answers in (b) must clearly relate to yield not to rate
(except for the qualification w.r.t. temperature)

any 7 points for 1 mark each

7

[11]

Q16.

(a) (i) *idea that it is*

a reaction in which the products can themselves react to reform the original substance or a reaction that can go in either direction

(allow explanation in terms of the specific reaction in the question)

for 1 mark

1

(ii) nitrogen, hydrogen and ammonia
(allow formulae)

for 1 mark

1

(b) (i) high pressure/400 atm
low temperature/100 °C

for 1 mark each

2

(ii) higher rate of reaction
good rate of production
or *idea* that more economic (ally viable)
(allow catalyst more effective at higher temperature)

for 1 mark each

2

(c) (i) *ideas that it involves*

use of catalyst

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gains 1 mark

but use of platinum catalyst
gains 2 marks

2

high temperature/900 °C
for 1 mark

1

(ii) $\underline{2}\ NO + O_2 \rightarrow \underline{2}NO_2$
for 1 mark each

1

(iii) $\underline{3}\ NO_2 + H_2O \rightarrow \underline{2H}NO_3 + NO$
for 1 mark each

1

(d) (i) references to

- transport reductions
- economic savings
- saves time
- guaranteed consumer/supplier
for 1 mark each

2

(ii)
- selection of site
- design of plant
- safe disposal of waste
- make gas emissions safe(r)
- monitoring/safety checks
- reduction of waste gas emissions
- research into more efficient processes
- research into energy savings/use of cooling water
- training of staff re: emergency procedures
- warning/evacuation procedures for the community

(or any two sensible suggestions)
any two for 1 mark each

2

[15]

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