AQA GCSE CHEMISTRY (HIGHER) · 8462

CHEMISTRY



MARK SCHEME

4.6.2 REVERSIBLE REACTIONS AND DYNAMIC EQUILIBRIUM (PACK 2)

SCORE	PERCENTAGE
/201	%

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Q1.

(a) 1213.8 to 1214.3

*gains **3** marks without working*

correct answer not given then check working

1) moles of N_2 = $\frac{1000}{28}$ = 35.7 mol

***1** mark for each correct step*
*do **not** penalise rounding errors in this part*

2) moles of NH_3 = 2 × (answer from (1)) = 71.4 mol

3) mass of NH_3 = (answer from 2) × 17 = 71.4 × 17 = 1214 g

3

or

- 28g of N_2 → 34g of NH_3

***1** mark for each correct step*

- 1g of N_2 → $\frac{34}{28}$ = 1.214g NH_3

*do **not** penalise rounding errors in this part*

- 1000 g of N_2 → 1000 × 1.214
  = 1214g

allow error carried forward eg

or

- 1000 × $\frac{34}{28}$

*gains **2** marks if correct answer not given*

*1000 × $\frac{28}{34}$ gains **1** mark, **2** marks if correctly calculated*

*(823.5g) 1000 × $\frac{28}{17}$ gains **1** mark if calculated correctly (1647.05g)*

or

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other correct methods

look for the key ideas in the methods above

(b) 25 **/** 25.035 **or** ecf from (a)

*gains **2** marks even when there is no working*

*incorrect answer then 304/(their answer from (a)) × 100 gains **1** mark*

or using figures from part (b)

27.6 / 28

*gains **2** marks even when there is no working*

*accept 27 for **1** mark*

*if answers incorrect then304/1100 × 100 gains **1** mark*

2

(c) (i) increase yield

1

reaction is exothermic

or

allow decreased yield because rate of reaction is slower / fewer collisions for **2** marks

***must** get both points for **2** marks*

1

(ii) increase yield

1

plus **one** from:

- more (gaseous) reactant molecules than (gaseous) product molecules (owtte)

  accept greater volume on the left than the right owtte

- increased rate of reaction / more collisions

1

(d) any **one** from:

economic

- large town provides workforce
- workers do not have to travel far to the factory. (owtte)
- transport infrastructure already in place for large town. (owtte)
- factory brings prosperity to town (owtte)
- factory provides employment
- reduced tourism
- reduction in local house prices

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- any other sensible economic factor linked to town

1

any **one** from:

safety

- escape of dangerous / harmful chemicals / gases (owtte)
  *do **not** allow polluting gases unqualified*
- danger of increased traffic
- risk of explosion.(owtte) /danger of high pressure
- consequences of an accident could be severe if the town is close
- any other sensible safety idea

1

any **one** from:

environmental

- factory might be unsightly (owtte)
- screening of factory (owtte)
- loss of habitats (owtte)
- plant trees/ hedges etc on and around plant site
- pollution of water / air / soil could harm plants / animals **or** noise pollution
  must be explained
- CO_2 is produced by burning fuels / heating
- CO_2 causes global warming / any effect of global warming
- eye sore
- any other sensible environmental factor

1

[12]

Q2.

(a) endothermic **and** because it takes in heat / energy
__both__ for one mark

1

(b) (i) reversible reaction (or explanation)

1

(ii) add water
*do **not** accept cooling **or** reverse the reaction*

1

[3]

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Q3.

(a) (i) high temperature

accept temperature given if ≥ 400 °C
ignore value if "high" stated, unless silly value

1

endothermic or reaction takes in energy
or Δ H is +ve

independent marks

1

(ii) low pressure

or up to and including 10 atmospheres

1

(low pressure) favours a reaction in which more molecules are formed

2 moles → 4 moles
(2 molecules → 4 molecules)

independent marks

1

(iii) nickel **and** it is a transition / transitional element / metal (owtte) **or** nickel **and** variable oxidation state / number or it is similar to other named transition elements e.g. iron

1

(b) (i) (bonds broken =) 2005 (kJ)

1

(bonds formed =) 2046 (kJ)

1

energy change = 2005 – 2046 = (–)41

for correct subtraction ignore sign

1

(ii) (exothermic)

if in part (b)(i) answer is not 41
answer is consequential on endothermic or exothermic shown

*accept correct reasoning for **incorrect** answer from (b)(i)*

energy given out forming new bonds

*do **not** accept energy needed to form new bonds*

1

greater than energy put in to break old bonds

*accept exothermic **and** more energy given out than taken in for 1 mark*
*accept negative value for energy change **or** energy in products less than energy in reactants for 1 mark*

1

[10]

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Q4.

(a) (i) high **and** low

both needed for mark

1

(ii) reversible

1

(iii) to prevent ammonium chloride / solid / particles escaping

idea of a filter
*do **not** accept 'to prevent gases escaping'*

1

(b) endothermic

1

[4]

Q5.

(a) ***2** marks for comments related to temperature*

low / lower / lowest temperature (**or** 100 °C from graph)

ignore references to catalyst

1

any **one** from:

- (forward) reaction exothermic

  ***or** reverse reaction endothermic*

- if the temperature is increased the yield of product will decrease **or** reaction right to left

  *high temperature favours reverse reaction **or** reverse argument*

  *the lower the temperature the greater the yield = **2** marks*

  ***2** marks for comments related to pressure*

1

high / higher / highest pressure (or greater than 200 atm. from graph)

1

any **one** from:

- four reactant molecules but only two product molecules (owtte)

  reverse reaction goes from 2 molecules / moles / volumes to 4 molecules / moles / volumes

- increase in pressure favours the reaction which produces the least number of molecules

  decrease in pressure favours the back reaction because it produces the most molecules

1

(b) any **three** from:

- at low temperatures the reaction is too slow

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- 450 °C gives a reasonable yield at a fast rate / compromise between yield and rate (*)
- 200 atm. gives a reasonable yield at a reasonable cost / safely / compromise between yield and cost / safety (*)

  *(*) or 450°C and 200 atm / these are compromise conditions for **1** mark*
- catalyst works better at higher temperature
- (very) high pressures could be dangerous (owtte)

  safety factor
- (very) high pressures are expensive (owtte)
- (yield is not too important because) unreacted gases can be recycled

3

[7]

Q6.

(a) (i) yield increases

two marks are linked

1

because more (gaseous) reactant molecules / particles than (gaseous) product molecules / particles

accept 7 → 4 moles or volumes
ignore more reactants
accept fewer particles on the right

1

(ii) increased (rate) / faster / speeds up etc

two marks are linked

1

more collisions **or** increased concentration **or** particles closer together

greater chance of more successful collisions

1

(b) heat / high temperatures

*do **not** accept burn it ignore cracking / catalyst*

1

[5]

Q7.

(i) reversible (reaction)

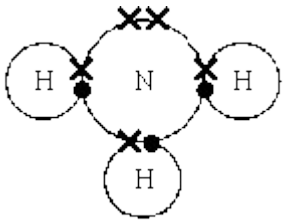
1

(ii) (yield of ammonia) increases

1

(iii)

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1

[3]

Q8.

(i) a reaction in which the products can be changed back to reactants

*accept a reaction that can go forwards **or** backwards*

1

under certain conditions

1

(ii) M_r $CaCO_3$ = 100

1

M_r CaO = 56

1

mass of CaO = 140 (tonnes)

1

mark consequentially

[5]

Q9.

(a) 16%

for 2 marks

(attempt by drawing lines etc gains 1 mark)

2

(b) iron is a catalyst;
which speeds up the reaction

for 1 mark each

2

(c) (from the graph) the best **yield** is obtained at high pressure;
and low temperature;
it is a reversible reaction;
in which formation of ammonia is favoured at low temperature (because) the reaction is exothermic;
and the formation of ammonia is favoured at high pressure because greater number of gaseous reactant molecules than gaseous product molecules/because greater vol of reactant than volume of product molecules;
pressure used is limited by cost/materials;
rate of reaction slow at low temperatures;
actual temperature and pressure used is a good compromise (between a good yield and reasonable rate);
removal of ammonia makes rate more important than yield;

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any 8 for 1 mark each

8

[12]

Q10.

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]

Q11.

(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]

Q12.

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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]

Q13.

(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

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(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

(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]

Q14.

(a) as a catalyst

accept to speed up the reaction (equilibrium)

1

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(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

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

1

[5]

Q15.

(a) endothermic (reaction)

accept thermal decomposition

1

(b) gives out heat (energy)

accept exothermic (reaction)

1

turns blue

accept goes to hydrated copper sulphate

1

[3]

Q16.

(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)

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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

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 <u>soil</u> 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** <u>different</u> 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

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do not credit <u>an</u> electron is shared

1

[10]

Q17.

(a) Bunsen (burner)

accept spirit burner do not credit candle

1

(b) blue

1

white

credit (1) if both colours correct but answers are reversed

1

to cool the tube (B)

*accept answers which anticipate part (d) e.g. 'to condense the water vapour' or gases **or** vapours*

1

(d) (i) water

do not credit 'condensation'

1

(ii) (Water) vapour from the crystals (from tube A)

*accept steam **or** steam from tube A*

1

condenses **or** cools

accept turns to (liquid) water

1

(e) add water

gets hot **or** hotter **or** warm **or** warmer turns into solution
dissolves

or the temperature rises or there is an exothermic reaction
*accept steams **or** hisses ignore any reference to colour(s)*

2

(f) sulphuric acid

accept H_2S0_4 only if correct in every detail

1

[10]

Q18.

(a) (i) atmosphere

or (fractional distillation of liquid) air

1

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

not just 'faster'

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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*

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]

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Q19.

(a) (i) 8

ammonia

do not credit ammonium

sulphuric acid

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]

Q20.

(a) (i) ammonia and hydrogen chloride

both required either order
accept formulae if correct in every detail

1

(ii) ammonium chloride / NH_4Cl

do not credit ammonia chloride

1

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(iii) the fumes / gases / are poisonous / toxic

or *ammonia and hydrogen chloride are poisonous / toxic / lethal*
accept just ammonia is poisonous / toxic
accept just hydrogen chloride is poisonous / toxic
accept vapour is poisonous / toxic
do not credit just fumes are dangerous
or *harmful*

1

(iv) nitrogen

do not credit N/N_2

1

hydrogen

do not credit H/H_2

1

molecule

do not credit compound ***or*** *mole*

1

covalent

accept single / molecular

1

(b) (i) proton

neutron

electron

either *all three correct*
or *one or two correct*
however do not credit a response which is repeated

2

(ii) protons and neutrons

both required in either order

1

[10]

Q21.

(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

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or *process is cheaper*
do not credit just it is cheaper

larger surface area
(than lumps of iron)

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]

Q22.

(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]

Q23.

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

any 4 answers for 1 mark each

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]

Q24.

(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)

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for 1 mark each

2

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

use of catalyst
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

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2

[15]

Q25.

(a) from natural gas [*allow from water/ steam / brine / river / lake / sea*]

for 1 mark

1

(b) *idea that* they are recycled / re-used

for 1 mark

1

(c) *ideas that*

- nitrates may get into ground water / rivers
- so contaminate / get into our drinking water
- eating animals which have eaten crop/ or eating contaminated fish

[do not allow 'eutrophication']

any two for 1 mark each

2

(d) (i) *idea that*
when rate of forward = rate of reverse reaction
[<u>not</u> just 'reversible' or 'can be reversed']
[allow ammonia is breaking up into nitrogen and hydrogen as fast as nitrogen and hydrogen are forming ammonia
<u>or</u> amounts of products and reactants stay constant*]*

for 1 mark

1

(ii) *ideas that*

- at higher temperatures, equilibrium moves to **the** left **or** reverse / endothermic
- reaction / favoured **or** makes products → reactants
- but at lower temperatures the (rate of) reaction is (very) slow
- so a higher temperature is used for economic reasons/so ammonia is produced at higher rate
- iron powder is a catalyst / speeds up the reaction

[<u>not</u> increases the yield]

- low yield not wasteful if reactants re-cycled

[<u>credit</u> iron powder has a greater surface area]

each for 1 mark

4

[9]

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