

**Chemistry
Standard level
Paper 2**

Key

Wednesday 16 May 2018 (afternoon)

1 hour 15 minutes

Candidate session number

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Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

Please do not write on this page.
Answers written on this page
will not be marked.



Answer all questions. Answers must be written within the answer boxes provided.

1. Urea, $(\text{H}_2\text{N})_2\text{CO}$, is excreted by mammals and can be used as a fertilizer.

- (a) (i) Calculate the percentage by mass of nitrogen in urea to two decimal places using section 6 of the data booklet. [2]

$$\begin{array}{l}
 \text{N} \rightarrow 2 \times 14.01 \text{ g/mol} = 28.02 \text{ g/mol} \\
 \text{H} \rightarrow 4 \times 1.01 \text{ g/mol} \\
 \text{C} \rightarrow 1 \times 12.01 \text{ g/mol} \\
 \text{O} \rightarrow 1 \times 16.00 \text{ g/mol} \\
 \hline
 60.07 \text{ g/mol}
 \end{array}
 \quad
 \frac{28.02 \text{ g/mol} \times 100\%}{60.07 \text{ g/mol}} = 46.65\%$$

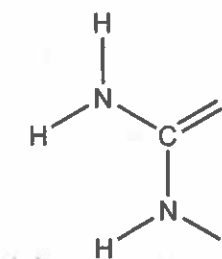
- (ii) Suggest how the percentage of nitrogen affects the cost of transport of fertilizers giving a reason. [1]

Since nitrogen is the only nutrient here for plant
 ~ 50% of the transport is dead weight.
 Compare to NH_3 - which carries virtually no dead weight.

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(Question 1 continued)

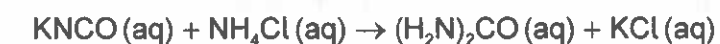
- (b) The structural formula of urea is shown.



Predict the electron domain and molecular geometries at the nitrogen and carbon atoms, applying the VSEPR theory.

	Electron domain geometry	Molecular geometry
Nitrogen	tetrahedral	trigonal pyramidal
Carbon	trigonal planar	trigonal planar

- (c) Urea can be made by reacting potassium cyanate, KNCO , with ammonium chloride, NH_4Cl .



Determine the maximum mass of urea that could be formed from 50.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ potassium cyanate solution. [2]

$$\text{KNCO } 50 \text{ mL} \times \frac{0.100 \text{ mol}}{\text{L}} \times \frac{1 (\text{H}_2\text{N})_2\text{CO}}{1 \text{ KNCO}} \times \frac{60.07 \text{ g}}{\text{mol}} = 300 \text{ mg}$$

or $3.00 \times 10^{-1} \text{ g}$

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(Question 1 continued)

- (d) Urea can also be made by the direct combination of ammonia and carbon dioxide gases.



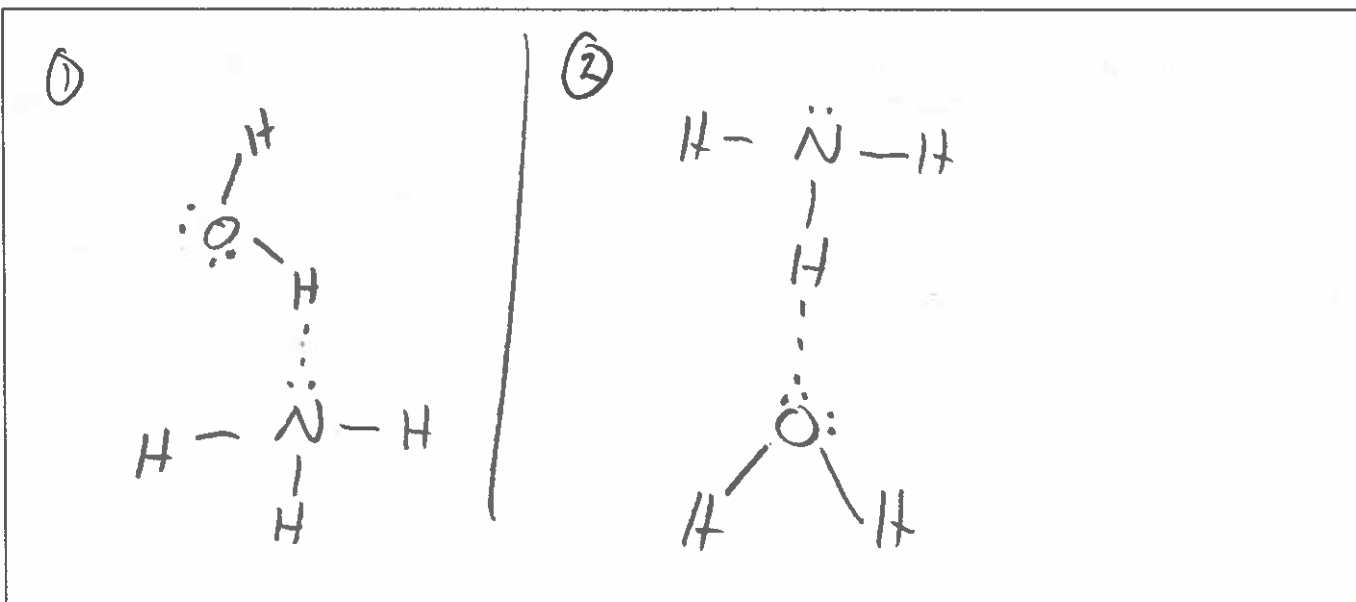
Predict, with a reason, the effect on the equilibrium constant, K_c , when the temperature is increased. [1]

Since $\Delta H < 0$, this reaction is exothermic. Since heat is a product, Le Chatelier's principle says equilibrium will shift to reactants. $K_c = \frac{[P]}{[R]}$ therefore K_c will decrease

- (e) (i) Suggest one reason why urea is a solid and ammonia a gas at room temperature. [1]

- While both have hydrogen bonding & d.pole-d.pole, urea has much larger London forces
 - C=O allows for 2 H-bonds to O & 1 H-bond per N (urea)
 NH₃ can only H bond to N

- (ii) Sketch two different hydrogen bonding interactions between ammonia and water. [2]

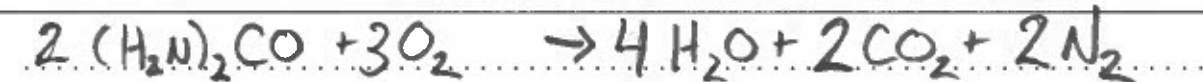


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(Question 1 continued)

- (f) The combustion of urea produces water, carbon dioxide and nitrogen.

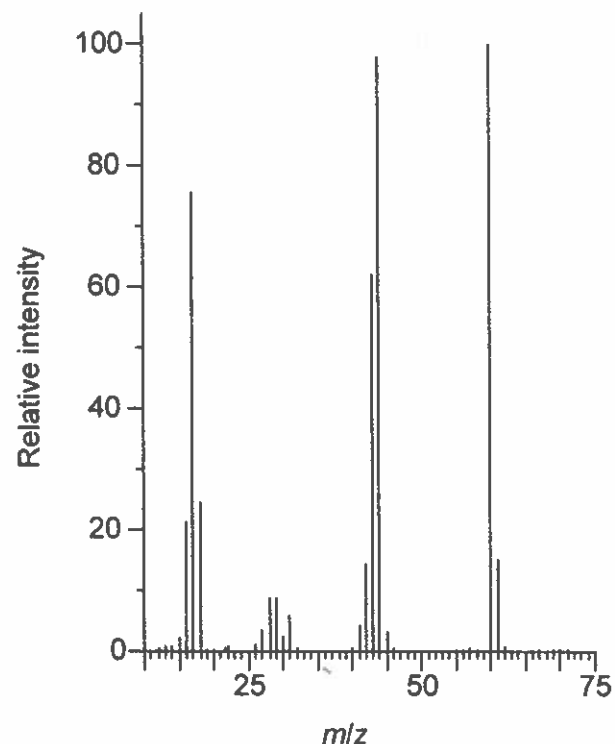
Formulate a balanced equation for the reaction. [2]



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(Question 1 continued)

(g) The mass spectrum of urea is shown below.



[Source: <http://sdbs.db.aist.go.jp>]

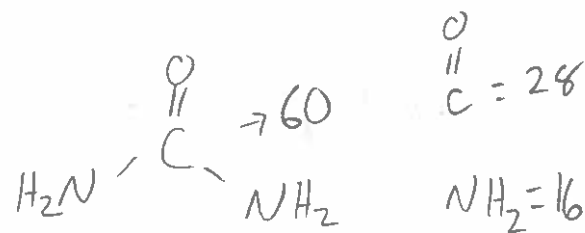
Identify the species responsible for the peaks at $m/z = 60$ and 44 .

[2]

60: urea $(\text{H}_2\text{N})_2\text{CO}^+$

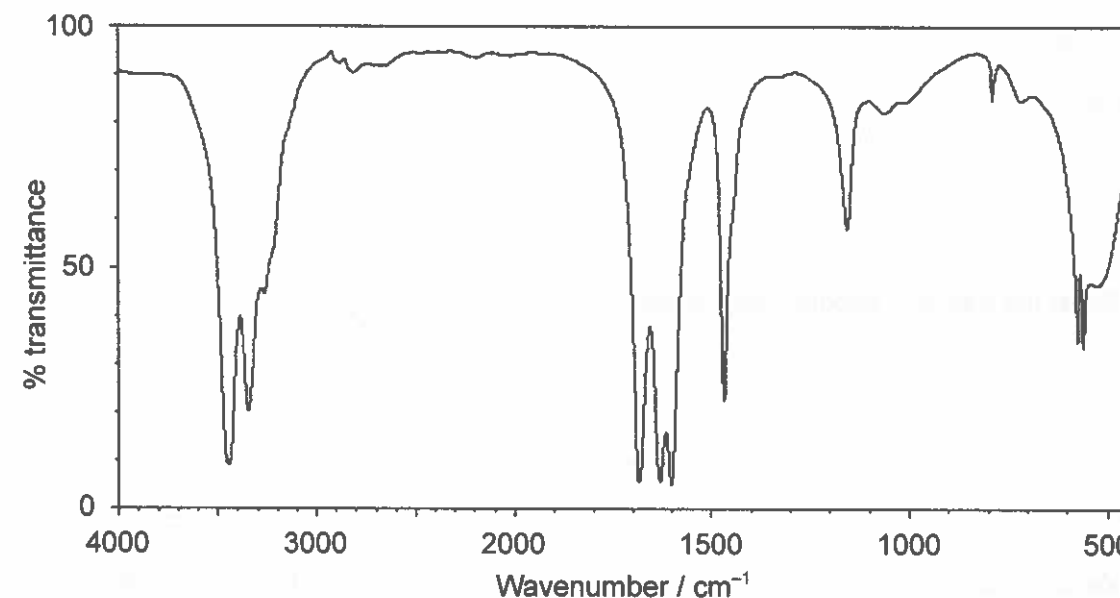
44: $\begin{array}{c} \text{O} \\ || \\ \text{C}-\text{NH}_2 \end{array}$ (60-16=44)

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(Question 1 continued)

(h) The IR spectrum of urea is shown below.



[Source: sdbs.db.aist.go.jp]

Identify the bonds causing the absorptions at 3450 cm^{-1} and 1700 cm^{-1} using section 26 of the data booklet.

[2]

3450 cm^{-1} : N-H

1700 cm^{-1} : $\begin{array}{c} \text{O} \\ || \\ \text{C} \end{array}$

(i) Predict the number of signals in the ^1H NMR spectrum of urea.

[1]

1

all H's are in identical environments

2. Calcium carbide, CaC_2 , is an ionic solid.

(a) Describe the nature of ionic bonding.

[1]

Two or more oppositely charged ions are attracted strongly to each other with electrostatic force.

(b) State the electron configuration of the Ca^{2+} ion.

[1]

$1s^2 2s^2 2p^6 3s^2 3p^6$

(c) When calcium compounds are introduced into a gas flame a red colour is seen; sodium compounds give a yellow flame. Outline the source of the colours and why they are different.

[2]

Flame colors arise from heat exciting the electrons of an atom. When an excited e^- falls back to $n=2$ visible light is seen.

(d) (i) Suggest two reasons why solid calcium has a greater density than solid potassium.

[2]

K has 1 valence e^- while Ca has 2. More delocalized e^- 's increases metallic bonding.

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(Question 2 continued)

(ii) Outline why solid calcium is a good conductor of electricity.

[1]

Calcium is a metal. Metals hold their valence electrons loosely, allowing them to delocalize. These unbound e^- move easily (electricity)

(e) Calcium carbide reacts with water to form ethyne and calcium hydroxide.



Estimate the pH of the resultant solution.

[1]

$\text{Ca}(\text{OH})_2 \rightarrow \text{Ca}^{2+} + 2\text{OH}^-$ | $\text{pH} > 7$ | Estimate $\text{pH} \approx 11$
 low solubility | partial dissociation

3. This question is about ethene, C_2H_4 , and ethyne, C_2H_2 .

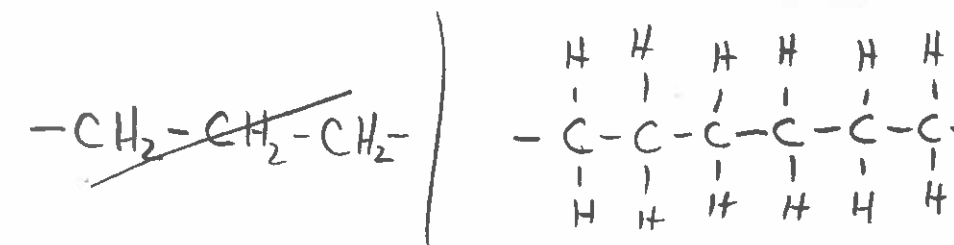
(a) (i) Ethyne, like ethene, undergoes hydrogenation to form ethane. State the conditions required.

[2]

Heat and a catalyst (usually Nickel)

(ii) Outline the formation of polyethene from ethene by drawing three repeating units of the polymer.

[1]



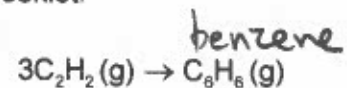
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(Question 3 continued)

- (b) (i) Under certain conditions, ethyne can be converted to benzene.

Determine the standard enthalpy change, ΔH^\ominus , for the reaction stated, using section 11 of the data booklet.

[2]

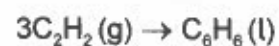


	Bond	KJ	#
$\Delta H^\ominus = \sum \text{BE broken} - \sum \text{BE formed}$ $= 3(1 \times 839 + 2 \times 414) - (6 \times 507 + 6 \times 414)$ $= 5001 - 5526$ $= -525 \text{ KJ} \rightarrow$	C=C	507	6
	C-H	414	6
	C≡C	839	1
	C-H	414	2

x3

- (ii) Determine the standard enthalpy change,
- ΔH^\ominus
- , for the following similar reaction, using
- ΔH_f
- values in section 12 of the data booklet.

[2]



$\Delta H^\ominus = \Delta H_{\text{EP}} - \Delta H_{\text{ER}}$ $= 490 - 3(228)$ $= -635 \text{ KJ}$

- (iii) Explain, giving two reasons, the difference in the values for (b)(i) and (ii). If you did not obtain answers, use
- -475 kJ
- for (i) and
- -600 kJ
- for (ii).

[2]

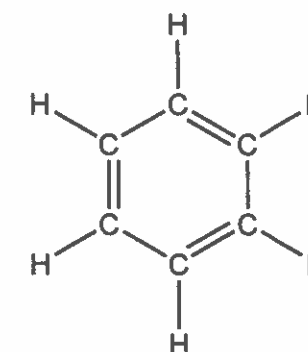
1) Bond enthalpies are averaged through experimentation while enthalpies of formation are precise.
2) forming gaseous and liquid benzene will require different amounts of energy

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(Question 3 continued)

- (c) One possible Lewis structure for benzene is shown.



State one piece of physical evidence that this structure is incorrect.

[1]

1- All C-C bonds are identical

- (d) State the characteristic reaction mechanism of benzene.

[1]

Electrophilic substitution

4. Calcium carbonate reacts with hydrochloric acid.



- (a) Outline two ways in which the progress of the reaction can be monitored. No practical details are required.

[2]

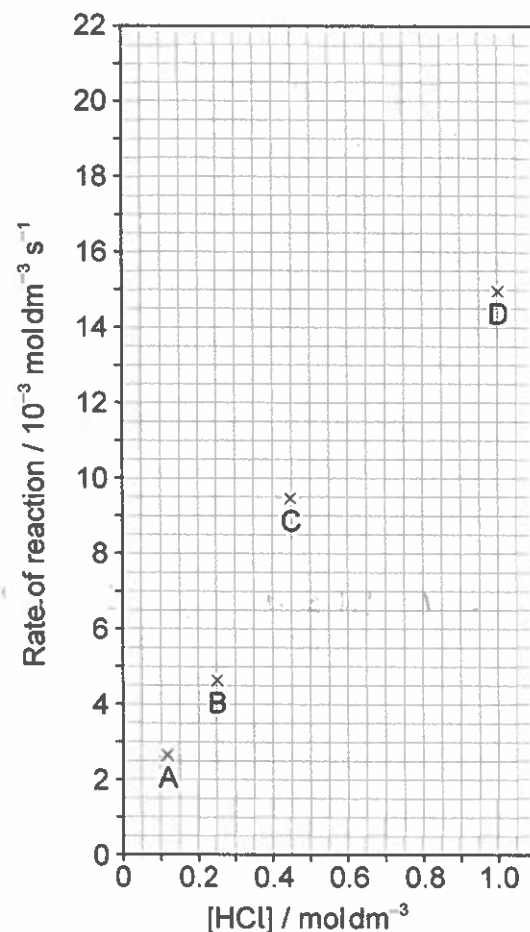
1) Formation of a gas (bubbling)	Volume of gas produced
2) disappearance of solid	loss of mass as CO_2 leaves
Not accepted	

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(Question 4 continued)

- (b) The results of a series of experiments in which the concentration of HCl was varied are shown below.



- (i) Suggest why point D is so far out of line assuming human error is not the cause. [1]

Increasing only 1 reactant (HCl) will have diminishing returns (seen as an asymptote) as reactant 2 (CaCO₃) will react maximally at some point.

- (ii) Suggest the relationship that points A, B and C show between the concentration of the acid and the rate of reaction. [1]

A, B and C show that acid concentration is proportional to reaction rate.

5. Limescale, CaCO₃ (s), can be removed from water kettles by using vinegar, a dilute solution of ethanoic acid, CH₃COOH (aq).

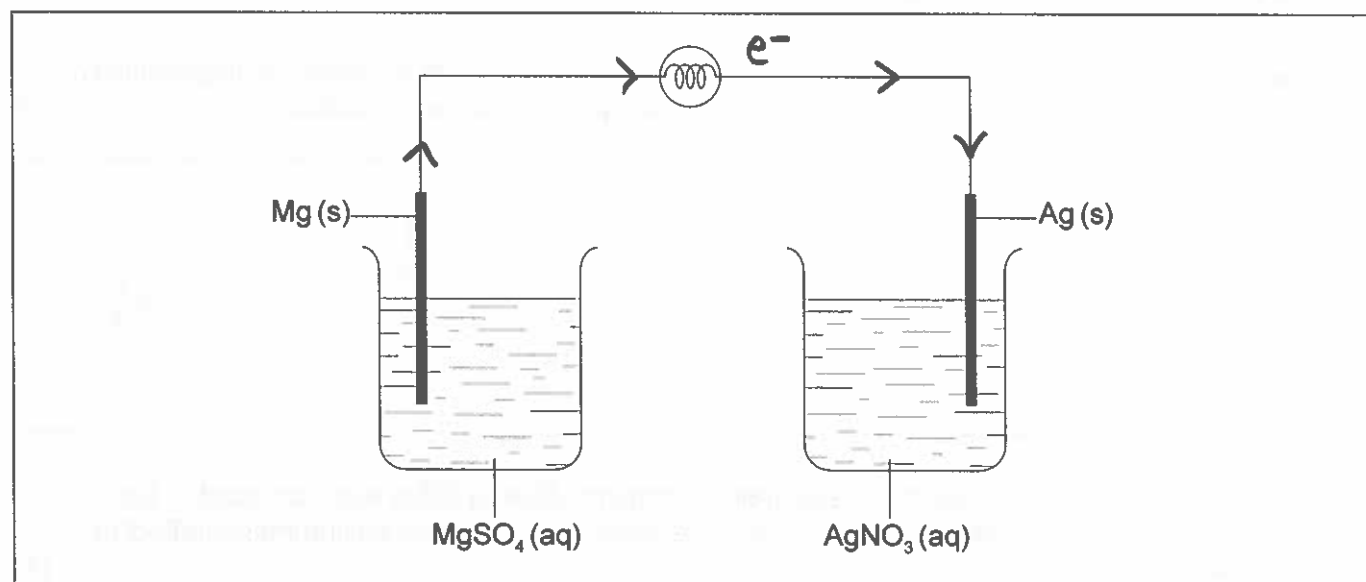
- (a) Predict, giving a reason, a difference between the reactions of the same concentrations of hydrochloric acid and ethanoic acid with samples of calcium carbonate. [2]

The reaction with HCl should happen more quickly because it is a strong acid donating >99% of its protons. Ethanoic acid is weak, donating only some of its protons.

- (b) Dissolved carbon dioxide causes unpolluted rain to have a pH of approximately 5, but other dissolved gases can result in a much lower pH. State one environmental effect of acid rain. [1]

Acid rain can lower the pH of lakes making it impossible for some species to survive.

6. The diagram shows an incomplete voltaic cell with a light bulb in the circuit.

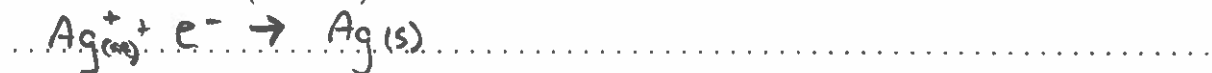


(a) Identify the missing component of the cell and its function. [2]

A salt bridge (U-tube w/ salt solution) is need to keep both electrolytes electrically neutral.

(b) Deduce the half-equations for the reaction at each electrode when current flows. [2]

Positive electrode (cathode):



Negative electrode (anode):



(c) Annotate the diagram with the location and direction of electron movement when current flows. [1]

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