



Please check the examination details below before entering your candidate information

Candidate surname

Other names

**Pearson Edexcel  
Level 3 GCE**

Centre Number

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Candidate Number

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**Tuesday 2 June 2020**

Afternoon (Time: 1 hour 45 minutes)

Paper Reference **9CH0/01**

**Chemistry**

**Advanced**

**Paper 1: Advanced Inorganic and Physical Chemistry**

**Candidates must have: Scientific calculator  
Data Booklet  
Ruler**

Total Marks

## Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided - *there may be more space than you need.*

## Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets - *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (\*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

## Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ►

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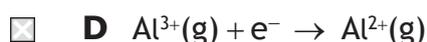
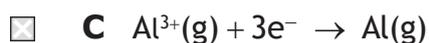
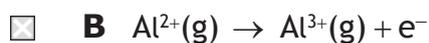
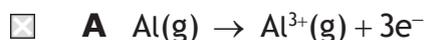


Answer ALL questions.

Some questions must be answered with a cross in a box. If you change your mind about an answer, put a line through the box and then mark your new answer with a cross.

1 (a) Which equation shows the third ionisation energy of aluminium?

(1)



(b) Which element in this table is in Group 2?

Element	Ionisation energy / $\text{kJ mol}^{-1}$			
	First	Second	Third	Fourth
W	1086	2353	4621	6223
X	653	1592	2987	4740
Y	590	1145	4912	6474
Z	496	4563	6913	9544

(1)

**A** W

**B** X

**C** Y

**D** Z

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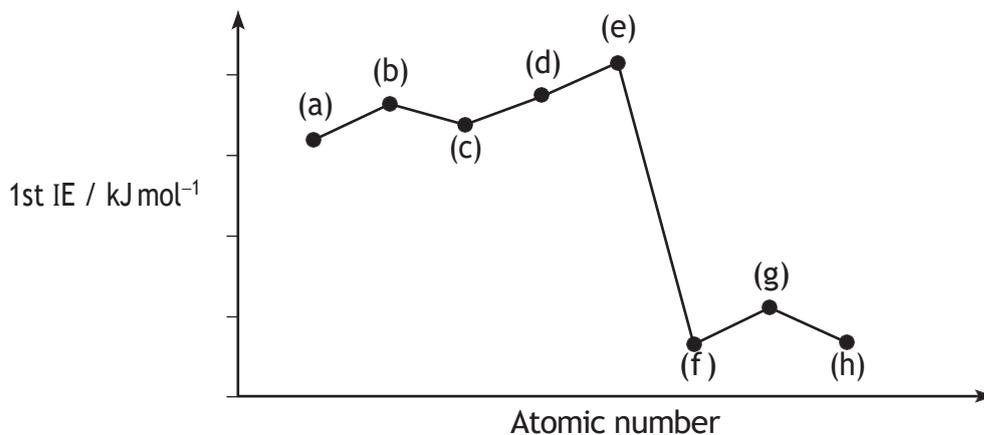
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(c) The graph shows the first ionisation energies (IE) of eight successive elements from the first 20 elements in the Periodic Table.

Which letter represents the first ionisation energy of oxygen?



(1)

- A (a)
- B (b)
- C (c)
- D (h)

(d) Give the formula of a stable **ion** that is isoelectronic with the magnesium ion,  $Mg^{2+}$ .

(1)





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(e) A student stated that ‘the elements scandium and zinc are d-block elements but are not transition metals’.

Discuss this statement, using appropriate electronic configurations to support your answer.

(4)

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**(Total for Question 1 = 8 marks)**





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2 This question is about acids and bases.

(a) What is the order of **decreasing** pH for 0.100 mol dm<sup>-3</sup> solutions of these three acids? (1)

- A CH<sub>3</sub>COOH > CH<sub>2</sub>ClCOOH > HCl
- B HCl > CH<sub>3</sub>COOH > CH<sub>2</sub>ClCOOH
- C CH<sub>2</sub>ClCOOH > CH<sub>3</sub>COOH > HCl
- D HCl > CH<sub>2</sub>ClCOOH > CH<sub>3</sub>COOH

(b) A solution of methanoic acid, HCOOH, has a concentration of 0.240 mol dm<sup>-3</sup> and a pH of 2.20.

Calculate the value of pK<sub>a</sub> for methanoic acid.

(3)

(c) Which of these mixtures would form a buffer solution with a pH **below** 7? (1)

- A NaOH(aq) and excess HCl(aq)
- B NaOH(aq) and excess CH<sub>3</sub>COOH(aq)
- C excess NaOH(aq) and HCl(aq)
- D excess NaOH(aq) and CH<sub>3</sub>COOH(aq)



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(d) Bromothymol blue, methyl orange and phenolphthalein are indicators used in titrations.

Which, if any, of these indicators could be used for a titration of ammonia,  $\text{NH}_3(\text{aq})$ , with ethanoic acid,  $\text{CH}_3\text{COOH}(\text{aq})$ ?

(1)

- A bromothymol blue
- B methyl orange
- C phenolphthalein
- D none of these three indicators

(Total for Question 2 = 6 marks)



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3 This question is about transition metals and transition metal complexes.

(a) Describe the bonding in the element chromium and use your answer to justify why it has such a high melting temperature.

You may find it helpful to draw a labelled diagram.

(4)

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(b) When chromium(III) sulfate dissolves in water, a green solution containing the  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$  ion forms.

(i) Give the shape of this complex ion.

(1)

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(ii) Explain why the chromium complex ion is coloured.

(3)

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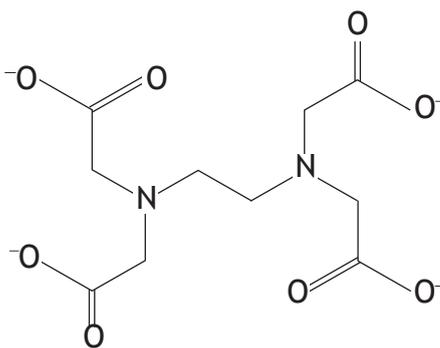


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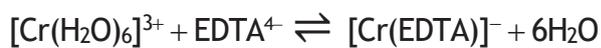
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(c) The ligand ethylenediaminetetraacetate,  $\text{EDTA}^{4-}$ , has the structure shown.



When a solution of  $\text{EDTA}^{4-}$  is added to a solution of  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$  ions, a new complex ion is formed.



The equilibrium constant for this equilibrium is  $2.51 \times 10^{23} \text{ dm}^3 \text{ mol}^{-1}$ .

By considering the equilibrium for this reaction and changes in entropy, comment on the value of the equilibrium constant. No calculations are required.

(3)

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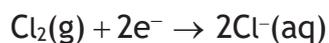
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- (d) Aqueous vanadium(II) chloride,  $\text{VCl}_2(\text{aq})$ , can be oxidised by bubbling gaseous chlorine,  $\text{Cl}_2(\text{g})$ , through the solution in the absence of air.

$40.0\text{ cm}^3$  of  $0.100\text{ mol dm}^{-3}$   $\text{VCl}_2$  solution was oxidised by  $144\text{ cm}^3$  of chlorine gas, at room temperature and pressure (r.t.p.).

The chlorine was reduced to chloride ions, according to the half-equation



[Molar volume of a gas at r.t.p. =  $24.0\text{ dm}^3\text{ mol}^{-1}$ ]

- (i) Use these data to calculate the final oxidation state of vanadium.  
You **must** show your working.

(5)

- (ii) State the initial and final colours you would see as the chlorine bubbles through the aqueous vanadium(II) chloride,  $\text{VCl}_2(\text{aq})$ .

(2)

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(Total for Question 3 = 18 marks)



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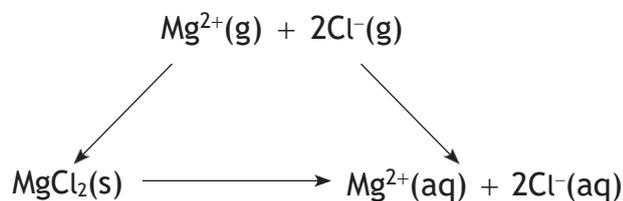
4 This question is about dissolving different compounds.

(a) Which of these compounds is the most soluble in water?

(1)

- A barium sulfate
- B calcium sulfate
- C magnesium sulfate
- D strontium sulfate

(b) What is the value, in  $\text{kJ mol}^{-1}$ , for the standard enthalpy change of solution of magnesium chloride?



$$\text{Lattice energy MgCl}_2(\text{s}) = -2526 \text{ kJ mol}^{-1}$$

$$\text{Hydration enthalpy of Cl}^{-}(\text{g}) = -381 \text{ kJ mol}^{-1}$$

$$\text{Hydration enthalpy of Mg}^{2+}(\text{g}) = -1921 \text{ kJ mol}^{-1}$$

(1)

- A +157
- B -157
- C +224
- D -224







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(Total for Question 4 = 8 marks)



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5 This question is about the chemistry of hydrated magnesium nitrate,  $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ .

(a) Group 2 nitrates decompose when heated.

(i) State **two** observations you would see when hydrated magnesium nitrate is heated. (2)

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(ii) Explain the trend in thermal stability of Group 2 nitrates. (3)

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(b) In an experiment, a sample of hydrated magnesium nitrate,  $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ , with a mass of 0.765 g, was dissolved in water and reacted with an excess of sodium hydroxide solution,  $\text{NaOH}(\text{aq})$ . The precipitate of magnesium hydroxide,  $\text{Mg}(\text{OH})_2$ , produced was removed and dried. The mass of the dried sample was 0.174 g.

(i) Draw dot-and-cross diagrams for the ions in magnesium hydroxide. Show the outer electrons only. (2)

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- (ii) Use the experimental data to calculate the value for  $x$  in the formula  $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ .  
You **must** show all your working.

(5)

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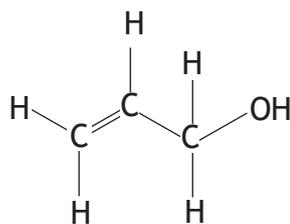
(Total for Question 5 = 12 marks)



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6 Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.



- (a) A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.
- (i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C bond as they could use the value for a C–C bond and multiply it by two.  
Explain why the student is **incorrect**.

(2)

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- (ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.



Bond	C–C	C=C	C–O	C=O	O–H	C–H	O=O
Bond enthalpy / $\text{kJ mol}^{-1}$	347	612	358	805	464	413	498

(3)

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(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.

(2)

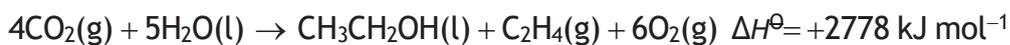
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(b) Chemists are researching a process to make ethanol and ethene directly from carbon dioxide and water.



	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$	$\text{CH}_3\text{CH}_2\text{OH}(\text{l})$	$\text{C}_2\text{H}_4(\text{g})$	$\text{O}_2(\text{g})$
$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$	213.6	69.9	160.7	219.5	205.0

Calculate  $\Delta S^\ominus_{\text{total}}$  for the reaction and hence determine whether the reaction is feasible under standard conditions.

(5)

(Total for Question 6 = 12 marks)

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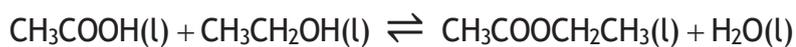
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- 7 A mixture of ethanoic acid, ethanol and a catalyst was left for several days to reach equilibrium.



The equilibrium constant,  $K_c$ , **under these conditions**, was 0.28.

- (a) (i) Write the expression for the equilibrium constant,  $K_c$ . (1)

- (ii) The initial amounts of ethanol and ethanoic acid used were 1.2 mol of each reactant.

Use this information, your expression for the equilibrium constant,  $K_c$ , and the value for  $K_c$ , to find the amounts of each product at equilibrium, in moles. (3)

Amount of  $\text{CH}_3\text{COOCH}_2\text{CH}_3$  = .....

Amount of  $\text{H}_2\text{O}$  = .....

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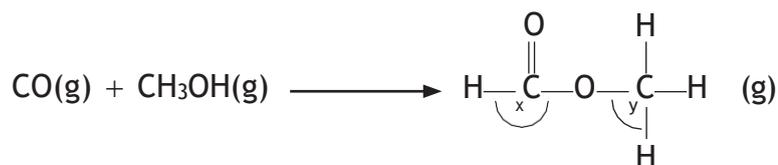


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(b) Another ester, methyl methanoate, can be formed by the reaction between methanol and carbon monoxide in the gaseous phase.



(i) The two O-C-H bond angles, x and y, in the ester are approximately (1)

- A 180° and 90°
- B 120° and 90°
- C 120° and 109.5°
- D 109.5° and 109.5°

(ii) The reaction often forms an equilibrium mixture.

Which could be the units for the equilibrium constant,  $K_p$ ? (1)

- A mol dm<sup>-3</sup>
- B dm<sup>3</sup> mol<sup>-1</sup>
- C atm
- D atm<sup>-1</sup>

(iii) Describe what effect, if any, increasing the pressure would have on the equilibrium constant,  $K_p$ . Justify your answer. (2)

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(Total for Question 7 = 8 marks)



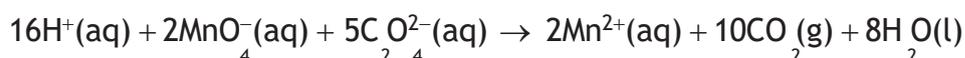


- 8 Tablets containing potassium manganate(VII),  $\text{KMnO}_4$ , are dissolved in water forming an antiseptic solution to treat skin conditions. The manufacturers claim that each tablet contains 400 mg of  $\text{KMnO}_4$ .

To check the claim, the titration procedure outlined was carried out.

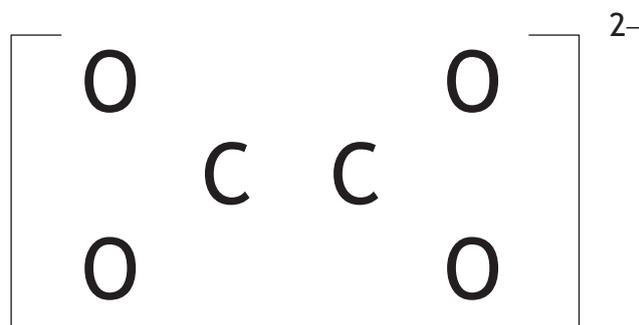
- Five tablets were dissolved in distilled water to make  $100.0 \text{ cm}^3$  of solution.
- Some of the  $\text{KMnO}_4$  solution was used to fill a burette.
- $25.0 \text{ cm}^3$  of sodium ethanedioate solution,  $\text{Na}_2\text{C}_2\text{O}_4(\text{aq})$ , of concentration  $0.200 \text{ mol dm}^{-3}$ , was added to a conical flask and warmed.
- Sulfuric acid, of concentration  $2 \text{ mol dm}^{-3}$ , was also added to the conical flask.
- The  $\text{KMnO}_4$  solution was added to the flask from the burette, until the end-point.

The equation for the reaction between  $\text{MnO}_4^-$  ions from the  $\text{KMnO}_4$  and  $\text{C}_2\text{O}_4^{2-}$  ions from the sodium ethanedioate solution is shown.



- (a) Give the colour **change** at the end-point of the titration. (1)

- (b) (i) Complete the dot-and-cross diagram for the ethanedioate ion.  
Show the outer electrons only. (2)



- (ii) Determine the oxidation number of carbon in the ethanedioate ion,  $\text{C}_2\text{O}_4^{2-}$ . (1)

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(c) Give the reason why sulfuric acid was also added to the conical flask.

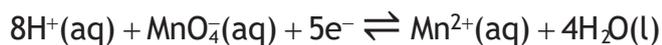
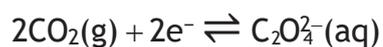
(1)

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(d) This redox reaction could be used in an electrochemical cell.

The cell half-equations are



Write a cell diagram for this cell using the conventional representation.

(2)

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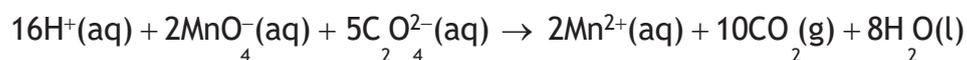
(e) The results of the titration are shown.

Run	Trial	1	2	3
Final volume / cm <sup>3</sup>	17.50	34.10	17.20	34.10
Initial volume / cm <sup>3</sup>	0.00	17.30	0.00	17.20
Titre / cm <sup>3</sup>	17.50		17.20	
Concordant titres (✓)				
Mean titre / cm <sup>3</sup>				

(i) Complete the table.

(2)

(ii) The equation for the reaction between  $\text{MnO}_4^-$  ions from the  $\text{KMnO}_4$  and  $\text{C}_2\text{O}_4^{2-}$  ions from the sodium ethanedioate solution is shown.



Use this equation and your mean titre from (e)(i) to calculate the mass, in mg, of  $\text{KMnO}_4$  in **one** tablet.

Give your answer to an appropriate number of significant figures.

(5)



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# The Periodic Table of Elements

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6.9 Li lithium	9.0 Be beryllium	23.0 Na sodium	24.3 Mg magnesium	39.1 K potassium	40.1 Ca calcium	45.0 Sc scandium	47.9 Ti titanium	50.9 V vanadium	52.0 Cr chromium	54.9 Mn manganese	55.8 Fe iron	58.9 Co cobalt	58.7 Ni nickel	63.5 Cu copper	65.4 Zn zinc	69.7 Ga gallium	72.6 Ge germanium	74.9 As arsenic	79.0 Se selenium	79.9 Br bromine	83.8 Kr krypton	85.5 Rb rubidium	87.6 Sr strontium	88.9 Y yttrium	91.2 Zr zirconium	92.9 Nb niobium	95.9 Mo molybdenum	98.0 Tc technetium	101.1 Ru ruthenium	102.9 Rh rhodium	106.4 Pd palladium	107.9 Ag silver	112.4 Cd cadmium	114.8 In indium	118.7 Sn tin	121.8 Sb antimony	127.6 Te tellurium	126.9 I iodine	131.3 Xe xenon	132.9 Cs caesium	137.3 Ba barium	138.9 La* lanthanum	148.9 Hf hafnium	183.8 Ta tantalum	186.2 W tungsten	190.2 Os osmium	192.2 Ir iridium	195.1 Pt platinum	197.0 Au gold	200.6 Hg mercury	204.4 Tl thallium	207.2 Pb lead	209.0 Bi bismuth	210.0 Po polonium	210.0 At astatine	222.0 Rn radon	223.0 Fr francium	226.0 Ra radium	227.0 Ac* actinium	262.0 Db dubnium	266.0 Sg seaborgium	271.0 Bh bohrium	277.0 Hs hassium	285.0 Mt meitnerium	289.0 Ds darmstadtium	294.0 Rg roentgenium	287.0 Uu unbinilium	288.0 Uub unbibium	289.0 Uut untrium	290.0 Uuq unquadium	291.0 Uuq unquadium	292.0 Uub unbibium	293.0 Uut untrium	294.0 Uuq unquadium	295.0 Uuq unquadium	296.0 Uub unbibium	297.0 Uut untrium	298.0 Uuq unquadium	299.0 Uuq unquadium	300.0 Uub unbibium	301.0 Uut untrium	302.0 Uuq unquadium	303.0 Uub unbibium	304.0 Uut untrium	305.0 Uuq unquadium	306.0 Uub unbibium	307.0 Uut untrium	308.0 Uuq unquadium	309.0 Uub unbibium	310.0 Uut untrium	311.0 Uuq unquadium	312.0 Uub unbibium	313.0 Uut untrium	314.0 Uuq unquadium	315.0 Uub unbibium	316.0 Uut untrium	317.0 Uuq unquadium	318.0 Uub unbibium	319.0 Uut untrium	320.0 Uuq unquadium	321.0 Uub unbibium	322.0 Uut untrium	323.0 Uuq unquadium	324.0 Uub unbibium	325.0 Uut untrium	326.0 Uuq unquadium	327.0 Uub unbibium	328.0 Uut untrium	329.0 Uuq unquadium	330.0 Uub unbibium	331.0 Uut 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