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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **October/November 2025**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **16** pages. Any blank pages are indicated.

DC (SL) 358970/2

1 Aqueous silver ions, $Ag^+(aq)$, react slowly with aqueous iron(II) ions, $Fe^{2+}(aq)$. An equilibrium is established.

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

The concentration of $Ag^+(aq)$ at equilibrium can be determined by titration with a standard solution of aqueous potassium thiocyanate, KSCN(aq).

During the titration, the remaining $Ag^+(aq)$ ions react with $SCN^-(aq)$ ions to form a precipitate of AgSCN(s).

$$Ag^+(aq) + SCN^-(aq) \rightarrow AgSCN(s)$$

When all $Ag^+(aq)$ ions have been removed from solution, excess $SCN^-(aq)$ ions react with $Fe^{3+}(aq)$ to form a complex ion, $FeSCN^{2+}(aq)$, which has a red colour.

$$Fe^{3+}(aq) + SCN^-(aq) \rightarrow FeSCN^{2+}(aq)$$

The appearance of the red colour indicates the end-point.

A student carries out an experiment to determine the equilibrium constant, K_c.

$$K_c = \frac{[Fe^{3+}(aq)]_{eqm}}{[Fe^{2+}(aq)]_{eqm}\,[Ag^+(aq)]_{eqm}}$$

The student makes $250.0\,cm^3$ of $0.0200\,mol\,dm^{-3}$ KSCN(aq) to use in the titration.

(a) Calculate the mass of solid potassium thiocyanate, KSCN(s), needed to make $250.0\,cm^3$ of $0.0200\,mol\,dm^{-3}$ KSCN(aq).

mass of KSCN(s) = ... g [1]

(b) Describe how the student should make 250.0 cm^3 of 0.0200 mol dm^{-3} KSCN(aq) starting from the mass of KSCN(s) calculated in **(a)** in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

....

....

....

....

....

....

.... [3]

(c) The student uses the following method to determine K_c.

step 1 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous silver nitrate, $AgNO_3$(aq), into a dry conical flask. Label this flask **A**.

step 2 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous iron(II) sulfate, $FeSO_4$(aq), into flask **A**.

step 3 Seal flask **A**, using a bung.

step 4 Allow flask **A** to stand for twelve hours.

step 5 Transfer 10.0 cm^3 of the mixture from flask **A** into another conical flask, flask **B**, without disturbing the precipitate in flask **A**.

step 6 Titrate the sample in flask **B** with 0.0200 mol dm^{-3} aqueous potassium thiocyanate, KSCN(aq).

step 7 Repeat steps 5 and 6 until concordant values are obtained.

(i) Suggest why flask **A** is sealed with a bung in step 3.

....

.... [1]

(ii) Suggest why flask **A** is left to stand for twelve hours in step 4.

....

.... [1]

(iii) Identify the precipitate in flask **A** in step 5.

.... [1]

(d) The student's results are shown in Table 1.1

Table 1.1

	rough titration	**titration 1**	**titration 2**	**titration 3**
final burette reading / cm^3	22.50	21.75	31.65	32.20
initial burette reading / cm^3	0.00	0.00	9.75	10.20
titre / cm^3	22.50	21.75	21.90	22.00

(i) State if concordant titres have been achieved.

Explain your answer.

....

.... [1]

(ii) Calculate the percentage error in the titre volume in titration 2.

Show your working.

percentage error = ... [1]

(iii) The student repeats the experiment using KSCN(aq) at a **higher** concentration. The student obtains **smaller** titres.

Suggest **one** reason why a larger titre is better than a smaller titre.

.... [1]

(e) Another student calculates a mean titre of 21.85 cm^3. Use this value to complete the following calculation.

(i) Calculate $[Ag^+(aq)]$ in the equilibrium mixture in flask **A**.

$[Ag^+(aq)]_{eqm}$ = ... $mol\,dm^{-3}$ [1]

(ii) Calculate $[Fe^{3+}(aq)]$ in the equilibrium mixture in flask **A**.

$[Fe^{3+}(aq)]_{eqm}$ = ... $mol\,dm^{-3}$ [1]

(iii) The formula for the equilibrium constant, K_c, is shown.

$$K_c = \frac{[Fe^{3+}(aq)]_{eqm}}{[Fe^{2+}(aq)]_{eqm}\,[Ag^+(aq)]_{eqm}}$$

Determine the value of K_c.

Give the units of K_c.

K_c = ...

units ....

[2]

(f) Several other students perform the same experiment at different temperatures. The K_c values that they obtain are used to produce the graph in Fig. 1.1.

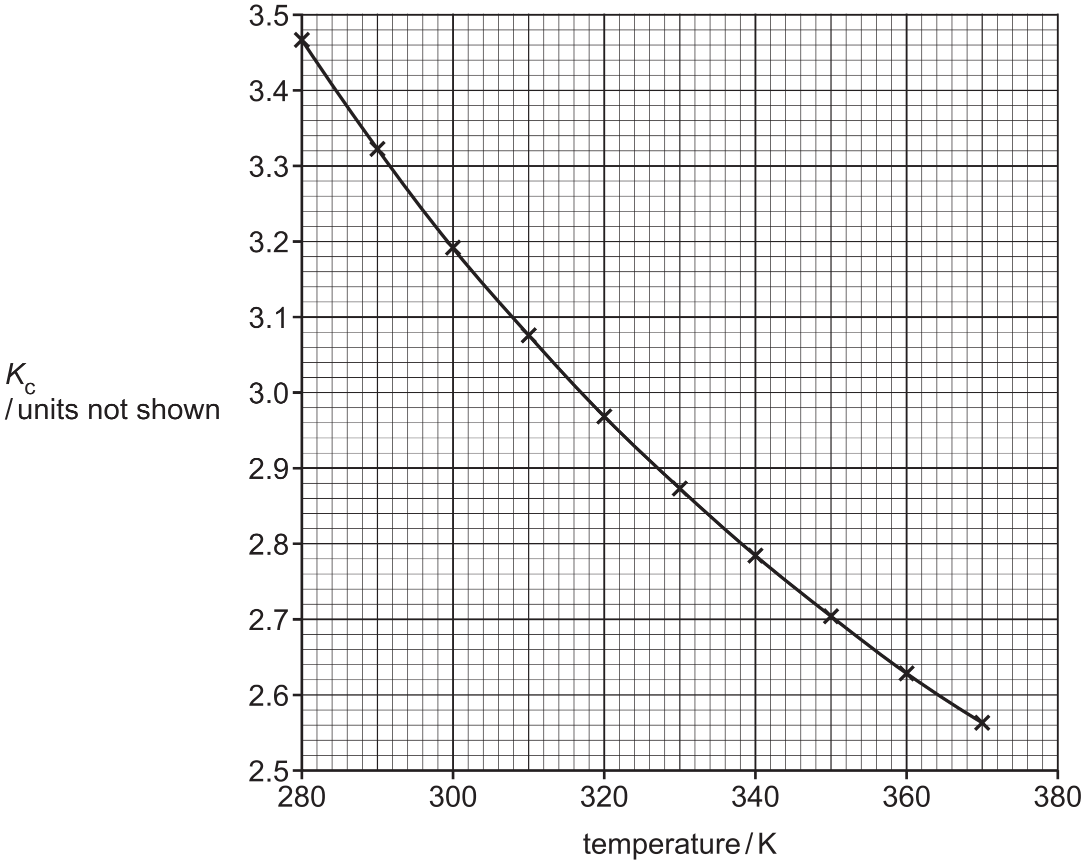

Fig. 1.1

(i) One student suggests that K_c is directly proportional to temperature.

State and explain if the results displayed in Fig. 1.1 support this suggestion.

....

.... [1]

(ii) Another student suggests that the data represented in the graph in Fig. 1.1 is reliable.

Explain how the graph supports this suggestion.

....

....

.... [1]

(iii) Use the data displayed in Fig. 1.1 to state if the forward reaction is exothermic or endothermic.

$$Ag^{+}(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

Explain your answer.

forward reaction ....

explanation ....

....

.... [1]

[Total: 17]

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2 A student carries out an experiment to determine the concentration of aqueous sulfate ions, $SO_4^{2-}(aq)$, in a sample of lake water.

(a) The student uses the following method.

step 1 Transfer 25.00 cm^3 of the lake water sample to a beaker and record its conductivity as shown in Fig. 2.1.

step 2 Add 5.00 cm^3 of 0.100 mol dm^{-3} aqueous barium hydroxide, $Ba(OH)_2(aq)$, to the beaker.

step 3 Stir the mixture and record the conductivity of the contents of the beaker as shown in Fig. 2.1.

step 4 Repeat steps 2 and 3 until a total of 40.00 cm^3 of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ has been added to the beaker.

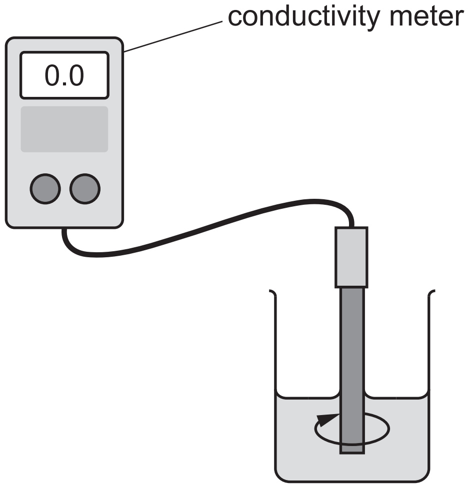

Fig. 2.1

(i) Suggest a suitable piece of apparatus to transfer 25.00 cm^3 of the lake water sample to the beaker in step 1.

.... [1]

(ii) 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ is an irritant to skin and eyes. Other than wearing safety goggles, state **one** safety precaution that the student should take when conducting this experiment.

.... [1]

(b) The student's results are given in Table 2.1.

A correction can be applied to the conductivity values to take into account dilution of the solution as its volume increases using the following equation.

$$\text{corrected conductivity} = \text{measured conductivity} \times \frac{\text{(total volume in beaker)}}{25.00}$$

Table 2.1

reading number	volume of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ added to beaker / cm^3	total volume in beaker / cm^3	measured conductivity / μS cm^{-1}	corrected conductivity / μS cm^{-1}
1	0.00	25.00	37 000	37 000
2	5.00		23 000	27 600
3	10.00		12 000	16 800
4	15.00		2 300	3 680
5	20.00		5 000	
6	25.00		12 000	
7	30.00		18 000	
8	35.00		21 000	
9	40.00		24 500	

(i) Complete Table 2.1. [2]

(ii) Identify the independent variable in this experiment.

.... [1]

(c) Plot a graph on the grid in Fig. 2.2 to show the relationship between corrected conductivity and volume of 0.100 mol dm^{-3} $Ba(OH)_2$ added to beaker.

Use a cross (×) to plot each data point.

Draw a line of best fit using readings 1 to 4 and another line of best fit using readings 5 to 9. Extend the lines so that they intersect.

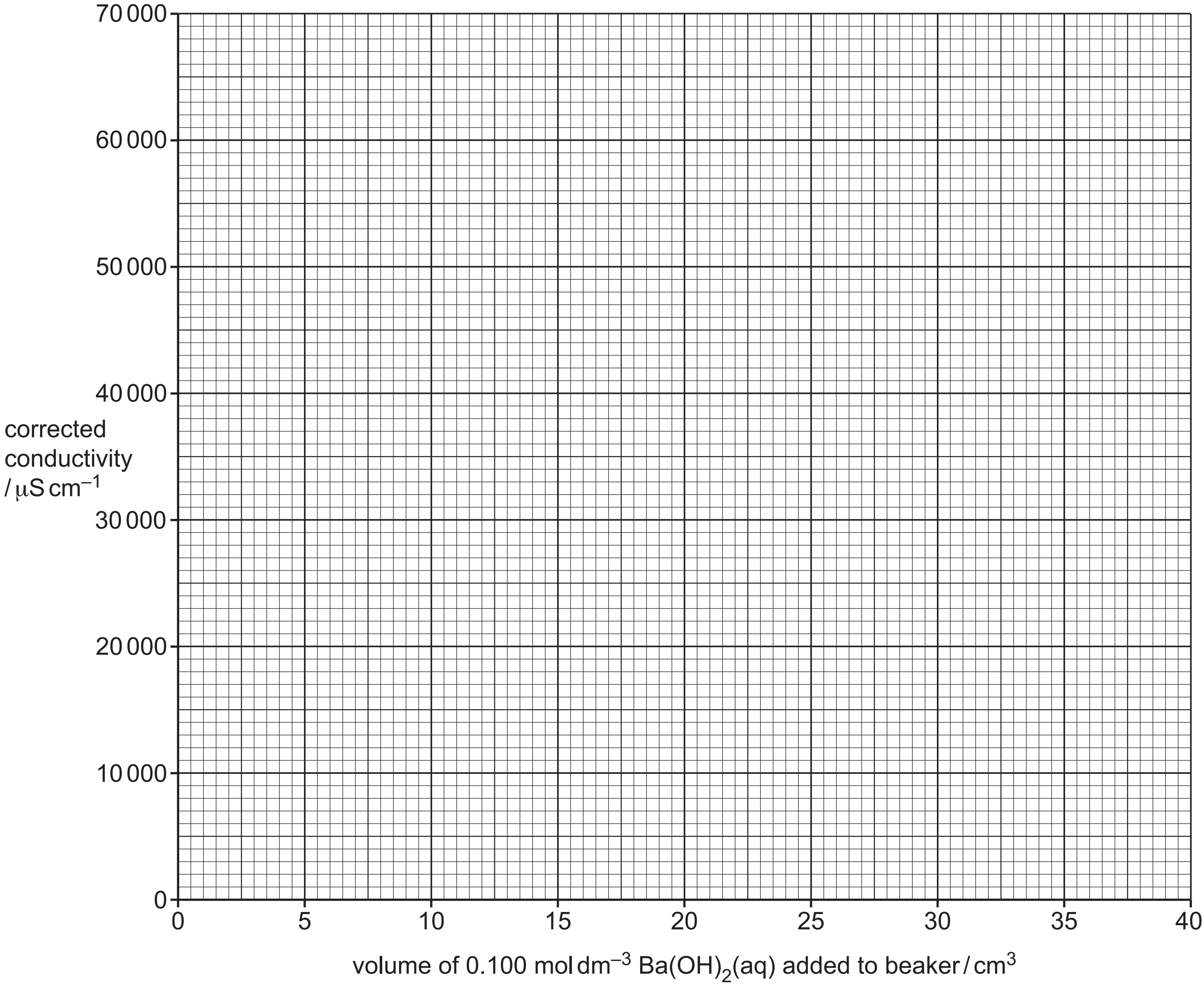

Fig. 2.2

[2]

(d) The point on the graph where the two lines intersect indicates the volume of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ required to react exactly with the $SO_4^{2-}(aq)$ present in 25.00 cm^3 of lake water being tested.

(i) Use the graph in Fig. 2.2 to determine the volume of 0.100 mol dm^{-3} $Ba(OH)_2(aq)$ required to react exactly with $SO_4^{2-}(aq)$ in the lake water sample.

volume required = ... cm^3 [1]

(ii) The equation for the reaction taking place in the beaker is shown.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Use your answer in **(d)(i)** to calculate the concentration of $SO_4^{2-}(aq)$ in the lake water sample.

concentration of $SO_4^{2-}(aq)$ = ... mol dm^{-3} [1]

(e) The concentration of SO_4^{2-}(aq) in a sample of water can also be determined by measuring the mass of precipitate produced when excess $Ba(OH)_2$(aq) is added to the sample.

The student suggests the following method.

step 1 Place 25.0 cm^3 of the water sample in a conical flask.

step 2 Add excess 0.100 $mol\,dm^{-3}$ $Ba(OH)_2$(aq) to the flask.

step 3 Filter the contents of the flask.

step 4 Dry the residue in a warm oven.

step 5 Measure the mass of residue.

(i) Draw a labelled diagram to describe the arrangement of apparatus that would be needed to complete step 3.

[1]

(ii) Suggest a step that the student should add between steps 3 and 4 to improve this method.

.... [1]

(iii) Describe what the student can do to ensure that the residue weighed in step 5 is completely dry.

....

.... [1]

(iv) The mass of residue is used to calculate the concentration of SO_4^{2-}(aq).

Suggest the effect, if any, on the concentration of SO_4^{2-}(aq) that is calculated if the residue is **not** completely dried in step 4.

Explain your answer.

effect on concentration of SO_4^{2-}(aq) calculated ....

explanation ....

....

[1]

[Total: 13]

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Important values, constants and standards

molar gas constant	$R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,\text{C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,\text{C}$
molar volume of gas	$V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

The Periodic Table of Elements

Key: atomic number / **atomic symbol** / name / relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –