



Cambridge International AS & A Level

CANDIDATE
NAME

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CHEMISTRY

9701/53

Paper 5 Planning, Analysis and Evaluation

October/November 2022

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 **12** pages.

- 1 A student attempts to determine the percentage by mass of magnesium chloride in the solid mixture containing magnesium chloride, $MgCl_2$, and anhydrous magnesium nitrate, $Mg(NO_3)_2$, using the following method.

step 1 Accurately weigh about 1.5g of the solid mixture and record the mass.

step 2 Dissolve the solid mixture in distilled water.

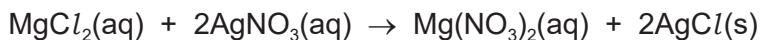
step 3 Add an excess of silver nitrate solution.

step 4 Filter the solid mixture and wash the precipitate collected with distilled water.

step 5 Dry the precipitate in an oven.

step 6 Weigh the precipitate and record the mass.

In this process only the chloride ions from the magnesium chloride form a precipitate with the silver nitrate solution.



One student in the class obtains the following results.

mass of solid mixture = 1.52g

mass of $AgCl$ solid after drying = 3.63g

- (a) (i) Calculate the amount, in mol, of magnesium chloride present in the sample.

amount of magnesium chloride = mol [1]

- (ii) Use your answer to (i) to calculate the percentage by mass of magnesium chloride in the sample. (If you were unable to answer (i) use 0.0102 mol. This is not the correct answer.)

percentage by mass = [2]

- (b) (i) Suggest what the student could do in **step 2** to ensure the solid dissolves as quickly as possible.

.....
.....
..... [1]

- (ii) Explain why the precipitate was washed with distilled water before it was dried.

.....
.....
.....

[1]

- (iii) Suggest why the precipitate is dried in an oven and not by direct heating with a Bunsen burner.

.....
.....
.....

[1]

- (c) (i) In **step 1**, a small beaker was weighed, using a balance accurate to two decimal places, and its mass recorded. The sample was placed in the beaker and the mass of the beaker increased by 1.52 g.

Calculate the percentage error in measuring the mass of this sample.

Show your working.

percentage error = [1]

- (ii) Other than by changing the balance, state how this percentage error could be reduced.

..... [1]

- (iii) State what could be done in **step 5** to ensure that the precipitate was completely dried.

.....
.....

[1]

- (d) Another student in the class did not dry their silver chloride.

State how this would affect the value of the percentage by mass of magnesium chloride in the sample. Explain your answer.

.....

[1]

[Total: 10]

- 2** Charles' law states that for a fixed mass of gas at constant pressure, its volume is proportional to its absolute temperature. Most gases are non-ideal and do not obey this law, but at lower pressures and high temperatures some gases are close to ideal behaviour. One gas that behaves like this is oxygen.

Oxygen can be prepared by decomposing hydrogen peroxide with the catalyst manganese(IV) oxide, MnO_2 .

The equation for the decomposition of hydrogen peroxide is shown.



Safety hazard: hydrogen peroxide is corrosive to skin and can cause serious eye damage.

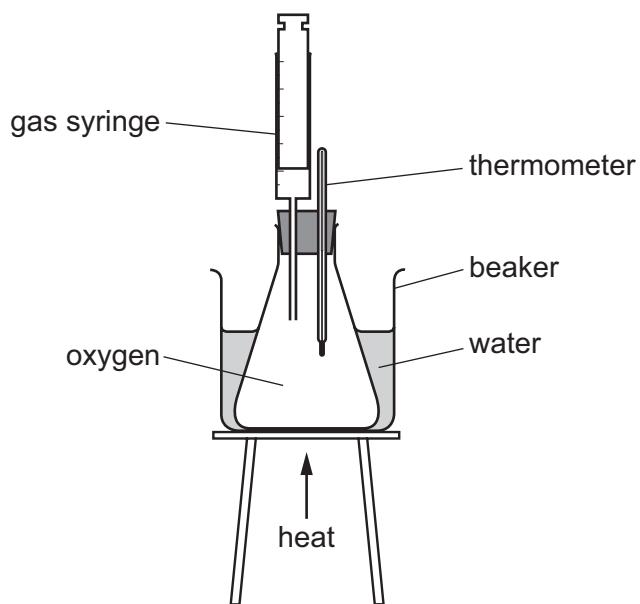


Fig. 2.1

Once the apparatus is assembled the volume of oxygen in the gas syringe is 2cm^3 . There are 80 cm^3 of oxygen remaining in the flask. The total volume of oxygen is 82 cm^3 .

Charles' law is investigated by the following method.

step 1 Once assembled allow the apparatus to reach room temperature.

step 2 Record this temperature and the total volume of oxygen reading on the syringe.

step 3 Gently heat the apparatus until the temperature reaches 30°C and record the total volume of oxygen.

step 4 Repeat at intervals of 5°C until the temperature reaches 70°C .

Question 2 continues on the next page.

The student carried out the experiment and obtained the following results:

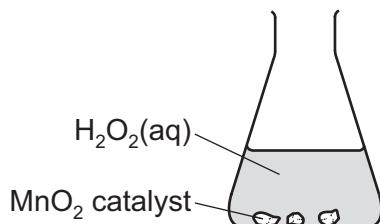
Table 2.1

temperature /°C	absolute temperature/K	total volume of oxygen gas/cm ³
24	297	82
30	303	84
35	308	88
40	313	88
45	318	89
50	323	91
55	328	93
60	333	95
65	338	97
70	343	98

- (a) Other than the wearing of safety goggles, give a safety precaution that the student must take during the preparation of oxygen.

..... [1]

- (b) (i) Complete the following diagram to show how the student can obtain oxygen by gas collection over water for use in the experiment shown in Fig. 2.1.

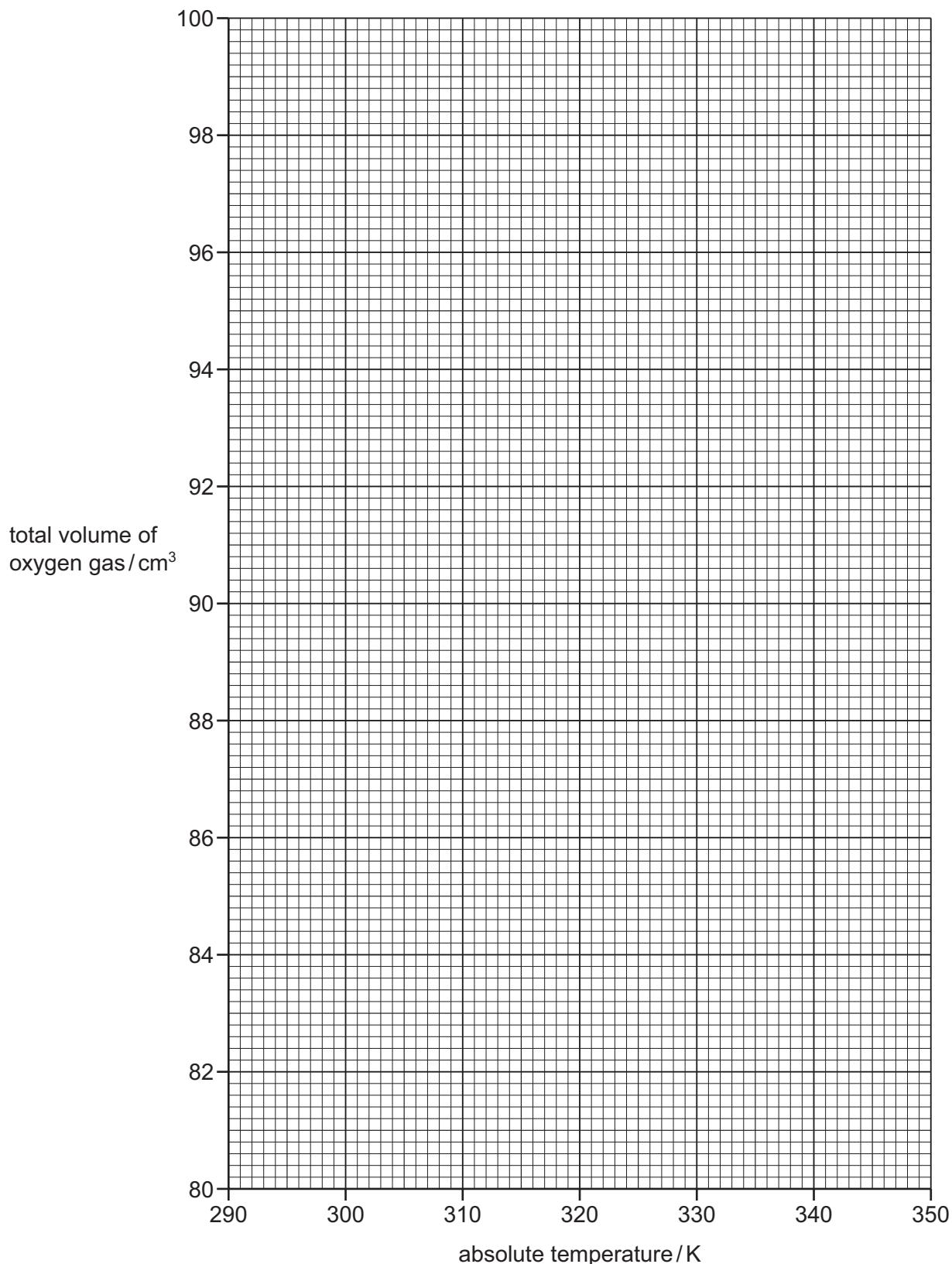


[2]

- (ii) Suggest how the student could ensure they collect pure oxygen gas in the conical flask.

..... [1]

- (c) (i) Plot a graph on the grid to show the relationship between volume of oxygen and absolute temperature. Use a cross (\times) to plot each data point. Draw a line of best fit.



[2]

- (ii) Determine the gradient of your line of best fit. State the coordinates of both points you used in your calculation. These must be selected from your line of best fit. Give the gradient to three significant figures.

coordinates 1 coordinates 2

gradient = cm^3K^{-1}

[2]

- (d) (i) On the graph, circle the point which you believe to be the most anomalous. [1]
- (ii) Suggest a possible explanation for this anomaly.

..... [1]

- (e) (i) Identify the independent variable.

..... [1]

- (ii) Suggest how the experiment could be made to be more reliable.

..... [1]

- (f) The ideal gas equation is shown.

$$pV = nRT$$

p = the pressure of the gas in Pa; V = the volume of gas in m^3 ; n = the number of moles of gas; R = the universal gas constant $8.31 \text{ J mol}^{-1}\text{K}^{-1}$ and T = absolute temperature in K

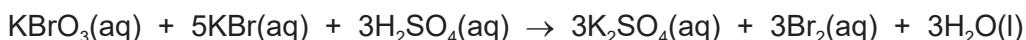
Using this equation, describe how the gradient of the graph you have plotted would be affected by using a smaller volume of oxygen at the start of the experiment. Explain your answer.

.....

 [1]

[Total: 13]

- 3 Potassium bromate(V) reacts with potassium bromide and sulfuric acid to form potassium sulfate, bromine and water according to the following equation.



A student is investigating how the rate of this reaction is affected by changing the concentration of the reactants in turn. This is done by keeping the total volume of mixture constant and adding different, small volumes of each reagent.

The reaction produces bromine which is orange in colour. The student times the reaction and then determines the rate as $\frac{1}{\text{time}}$.

The rate equation for the reaction is of the form:

$$\text{rate} = k[\text{KBrO}_3]^x[\text{KBr}]^y[\text{H}_2\text{SO}_4]^z$$

k is the rate constant for the reaction and x , y and z are the respective orders of the reaction for each reagent.

The student carried out the experiment and obtained the following data.

Table 3.1

mixture	$[\text{KBrO}_3]$ /mol dm $^{-3}$	$[\text{KBr}]$ /mol dm $^{-3}$	$[\text{H}_2\text{SO}_4]$ /mol dm $^{-3}$	rate of reaction $/\text{s}^{-1}$
A	0.025	0.125	0.075	0.059
B	0.050	0.125	0.075	0.117
C	0.025	0.250	0.075	0.118
D	0.025	0.125	0.150	0.235
E	0.050	0.250	0.150	0.941

- (a) (i) Suggest how the student might time the reaction and judge the end point of the reaction for each mixture.

.....
.....
.....

[1]

- (ii) By comparing the data for the mixtures deduce the values of x , y and z .

[2]

- (b) The student carried out each reaction using a boiling tube (capacity 50 cm^3) and varied the concentration by adding different volumes of each reagent. For example, in mixture A, 5.0 cm^3 of $\text{KBrO}_3(\text{aq})$ is required.

Name a suitable piece of apparatus which could be used to measure this volume.

..... [1]

- (c) Suggest why the reagents are heated to the same temperature before mixing.

..... [1]

- (d) The solution of sulfuric acid used in each mixture was of concentration 0.150 mol dm^{-3} . This acid was prepared from a solution of concentration 1 mol dm^{-3} .

Briefly describe how to make the more dilute solution, stating the capacity of any apparatus used.

.....
.....
.....
..... [2]

[Total: 7]

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	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
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

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3	Li	4	B	Be	beryllium	9.0					B	boron	10.8	C	carbon	12.0	N	nitrogen	O	oxygen	F	fluorine	Ne	neon																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
11	Na	12	Mg	magnesium	24.3	23.0	20	Ca	Sc	scandium	45.0	21	Ti	titanium	47.9	V	chromium	52.0	Cr	cobalt	55.8	Co	copper	63.5	10	He	helium																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
19	K	39.1	Rb	rubidium	85.5	85.5	38	Sr	Y	yttrium	88.9	39	Zr	zirconium	91.2	Nb	niobium	92.9	Mo	molybdenum	95.9	Tc	technetium	—	10.8	H	hydrogen																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
55	Cs	132.9	Ba	barium	137.3	137.3	56	La	lanthanoids	57–71	Hf	hafnium	178.5	72	Ta	tantalum	180.9	W	tungsten	183.8	Re	rhenium	186.2	Os	osmium	190.2	7	He	helium																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
87	Fr	—	Ra	radium	—	—	88	Ac	actinoids	89–103	Rf	rutherfordium	—	104	Db	dubnium	—	105	Ds	ds	—	106	Bh	bohrium	—	107	Hs	hassium	—	108	Tl	thallium	121.8	109	Pt	platinum	195.1	110	Ir	iridium	192.2	111	Os	osmium	190.2	112	Pd	palladium	106.4	113	Ag	silver	107.9	114	Cd	cadmium	112.4	115	Sn	tin	118.7	116	Ge	germanium	69.7	117	In	indium	114.8	118	Ge	germanium	69.7	119	As	arsenic	72.6	120	Ge	germanium	69.7	121	As	arsenic	72.6	122	Zn	zinc	65.4	123	Ge	germanium	69.7	124	Ge	germanium	69.7	125	Zn	zinc	65.4	126	Ge	germanium	69.7	127	Ge	germanium	69.7	128	Ge	germanium	69.7	129	Ge	germanium	69.7	130	Ge	germanium	69.7	131	Ge	germanium	69.7	132	Ge	germanium	69.7	133	Ge	germanium	69.7	134	Se	selenium	79.0	135	Br	bromine	79.9	136	Kr	krypton	83.8	137	Xe	xenon	131.3	138	Rn	radon	—	139	At	astatine	—	140	Lu	lutetium	175.0	141	Yb	ytterbium	173.1	142	No	nobelium	—	143	Lu	lutetium	175.0	144	Er	erbium	167.3	145	Tm	thulium	168.9	146	Ho	holmium	164.9	147	Dy	dysprosium	162.5	148	Tb	terbium	158.9	149	Gd	gadolinium	157.3	150	Sm	samarium	150.4	151	Eu	europium	152.0	152	Pr	praseodymium	144.4	153	Nd	neodymium	144.4	154	Pa	protactinium	231.0	155	Pu	plutonium	—	156	Cm	americium	—	157	Bk	berkelium	—	158	Cf	californium	—	159	Es	einsteinium	—	160	Fm	fermium	—	161	Md	mendelevium	—	162	Mc	moscovium	—	163	Lv	livermorium	—	164	Ts	tennessine	—	165	Qg	oganesson	—	166	Lu	lutetium	—	167	Yb	ytterbium	—	168	Lu	lutetium	—	169	Er	erbium	—	170	Tm	thulium	—	171	Ho	holmium	—	172	Dy	dysprosium	—	173	Tb	terbium	—	174	Gd	gadolinium	—	175	Sm	samarium	—	176	Eu	europium	—	177	Pr	praseodymium	—	178	Nd	neodymium	—	179	Pa	protactinium	—	180	Pu	plutonium	—	181	Cm	americium	—	182	Bk	berkelium	—	183	Cf	californium	—	184	Es	einsteinium	—	185	Fm	fermium	—	186	Md	mendelevium	—	187	Mc	moscovium	—	188	Lv	livermorium	—	189	Qg	oganesson	—	190	Lu	lutetium	—	191	Yb	ytterbium	—	192	Lu	lutetium	—	193	Er	erbium	—	194	Tm	thulium	—	195	Ho	holmium	—	196	Dy	dysprosium	—	197	Tb	terbium	—	198	Gd	gadolinium	—	199	Sm	samarium	—	200	Eu	europium	—	201	Pr	praseodymium	—	202	Nd	neodymium	—	203	Pa	protactinium	—	204	Pu	plutonium	—	205	Cm	americium	—	206	Bk	berkelium	—	207	Cf	californium	—	208	Es	einsteinium	—	209	Fm	fermium	—	210	Md	mendelevium	—	211	Mc	moscovium	—	212	Lv	livermorium	—	213	Qg	oganesson	—	214	Lu	lutetium	—	215	Yb	ytterbium	—	216	Lu	lutetium	—	217	Er	erbium	—	218	Tm	thulium	—	219	Ho	holmium	—	220	Dy	dysprosium	—	221	Tb	terbium	—	222	Gd	gadolinium	—	223	Sm	samarium	—	224	Eu	europium	—	225	Pr	praseodymium	—	226	Nd	neodymium	—	227	Pa	protactinium	—	228	Pu	plutonium	—	229	Cm	americium	—	230	Bk	berkelium	—	231	Cf	californium	—	232	Es	einsteinium	—	233	Fm	fermium	—	234	Md	mendelevium	—	235	Mc	moscovium	—	236	Lv	livermorium	—	237	Qg	oganesson	—	238	Lu	lutetium	—	239	Yb	ytterbium	—	240	Lu	lutetium	—	241	Er	erbium	—	242	Tm	thulium	—	243	Ho	holmium	—	244	Dy	dysprosium	—	245	Tb	terbium	—	246	Gd	gadolinium	—	247	Sm	samarium	—	248	Eu	europium	—	249	Pr	praseodymium	—	250	Nd	neodymium	—	251	Pa	protactinium	—	252	Pu	plutonium	—	253	Cm	americium	—	254	Bk	berkelium	—	255	Cf	californium	—	256	Es	einsteinium	—	257	Fm	fermium	—	258	Md	mendelevium	—	259	Mc	moscovium	—	260	Lv	livermorium	—	261	Qg	oganesson	—	262	Lu	lutetium	—	263	Yb	ytterbium	—	264	Lu	lutetium	—	265	Er	erbium	—	266	Tm	thulium	—	267	Ho	holmium	—	268	Dy	dysprosium	—	269	Tb	terbium	—	270	Gd	gadolinium	—	271	Sm	samarium	—	272	Eu	europium	—	273	Pr	praseodymium	—	274	Nd	neodymium	—	275	Pa	protactinium	—	276	Pu	plutonium	—	277	Cm	americium	—	278	Bk	berkelium	—	279	Cf	californium	—	280	Es	einsteinium	—	281	Fm	fermium	—	282	Md	mendelevium	—	283	Mc	moscovium	—	284	Lv	livermorium	—	285	Qg	oganesson	—	286	Lu	lutetium	—	287	Yb	ytterbium	—	288	Lu	lutetium	—	289	Er	erbium	—	290	Tm	thulium	—	291	Ho	holmium	—	292	Dy	dysprosium	—	293	Tb	terbium	—	294	Gd	gadolinium	—	295	Sm	samarium	—	296	Eu	europium	—	297	Pr	praseodymium	—	298	Nd	neodymium	—	299	Pa	protactinium	—	300	Pu	plutonium	—	301	Cm	americium	—	302	Bk	berkelium	—	303	Cf	californium	—	304	Es	einsteinium	—	305	Fm	fermium	—	306	Md	mendelevium	—	307	Mc	moscovium	—	308	Lv	livermorium	—	309	Qg	oganesson	—	310	Lu	lutetium	—	311	Yb	ytterbium	—	312	Lu	lutetium	—	313	Er	erbium	—	314	Tm	thulium	—	315	Ho	holmium	—	316	Dy	dysprosium	—	317	Tb	terbium	—	318	Gd	gadolinium	—	319	Sm	samarium	—	320	Eu	europium	—	321	Pr	praseodymium	—	322	Nd	neodymium	—	323	Pa	protactinium	—	324	Pu	plutonium	—	325	Cm	americium	—	326	Bk	berkelium	—	327	Cf	californium	—	328	Es	einsteinium	—	329	Fm	fermium	—	330	Md	mendelevium	—	331	Mc	moscovium	—	332	Lv	livermorium	—	333	Qg	oganesson	—	334	Lu	lutetium	—	335	Yb	ytterbium	—	336	Lu	lutetium	—	337	Er	erbium	—	338	Tm	thulium	—	339	Ho	holmium	—	340	Dy	dysprosium	—	341	Tb	terbium	—	342	Gd	gadolinium	—	343	Sm	samarium	—	344	Eu	europium	—	345	Pr	praseodymium	—	346	Nd	neodymium	—	347	Pa	protactinium	—	348	Pu	plutonium	—	349	Cm	americium	—	350	Bk	berkelium	—	351	Cf	californium	—	352	Es	einsteinium	—	353	Fm	fermium	—	354	Md	mendelevium	—	355	Mc	moscovium	—	356	Lv	livermorium	—	357	Qg	oganesson	—	358	Lu	lutetium	—	359	Yb	ytterbium	—	360	Lu	lutetium	—	361	Er	erbium	—	362	Tm	thulium	—	363	Ho	holmium	—	364	Dy	dysprosium	—	365	Tb	terbium	—	366	Gd	gadolinium	—	367	Sm	samarium	—	368	Eu	europium	—	369	Pr	praseodymium	—	370	Nd	neodymium	—	371	Pa	protactinium	—	372	Pu	plutonium	—	373	Cm	americium	—	374	Bk	berkelium	—	375	Cf	californium	—	376	Es	einsteinium	—	377	Fm	fermium	—	378	Md	mendelevium	—	379	Mc	moscovium	—	380	Lv	livermorium	—	381	Qg	oganesson	—	382	Lu	lutetium	—	383	Yb	ytterbium	—	384	Lu	lutetium	—	385	Er	erbium	—	386	Tm	thulium	—	387	Ho	holmium	—	388	Dy	dysprosium	—	389	Tb	terbium	—	390	Gd	gadolinium	—	391	Sm	samarium	—	392	Eu	europium	—	393	Pr	praseodymium	—	394	Nd	neodymium	—	395	Pa	protactinium	—	396	Pu	plutonium	—	397	Cm	americium	—	398	Bk	berkelium	—	399	Cf	californium	—	400	Es	einsteinium	—	401	Fm	fermium	—	402	Md	mendelevium	—	403	Mc	moscovium	—	404	Lv	livermorium	—	405	Qg	oganesson	—	406	Lu	lutetium	—	407	Yb	ytterbium	—	408	Lu	lutetium	—	409	Er	erbium	—	410	Tm	thulium	—	411	Ho	holmium	—	412	Dy	dysprosium	—	413	Tb	terbium	—	414	Gd	gadolinium