REMARKS

In response to the final Office action ("Final Office Action") dated January 16, 2020, Applicant has incorporated claims 77 and 74 into claims 36 and 66, respectively, and cancelled claims 74 and 77. Applicant has also amended claims 36 and 66 to correct minor deficiencies. Claims 36, 37, 39, 43-45, 66-73, 75, and 76 are presented for examination.

Interview Summary

Applicant would like to thank the Examiner for the telephone interview with the undersigned on February 20, 2020.

During the interview, the patentability of the pending claims was discussed in view of the issues raised in the final Office action. Specifically, with respect to the lack of utility rejection, the Examiner did not dispute that isotope Mo-99 was not in the stable Mo powder used in the experiment described at pages 12-13 of the Specification as originally filed that resulted in Figure 2. On the other hand, the Examiner was not sure whether the signal of Tc-99m in Figure 2 was from the sample or from the environment. To overcome this rejection, the Examiner suggested that Applicant presents a declaration or a published peer-reviewed article demonstrating that the signal of Tc-99m was produced from the sample.

In addition, the Examiner agreed that, if Applicant overcomes the lack of utility rejection, the lack of enablement rejection would also be overcome. She also agreed that the above-proposed amendments (including incorporating claims 77 and 74 into claims 36 and 66, respectively) would overcome the indefiniteness, anticipation, and obviousness rejections. Lastly, the Examiner conceded that she missed the priority claim to U.S. Application No. 12/361,540 (i.e., the parent of the present application) and agreed to withdraw the new matter objection to the Specification once Applicant files a formal reply to the final Office action.

Pursuant to the above discussion, Applicant files the present reply with a Declaration by Mr. Tahan supporting the utility of the claimed systems.

Other points discussed during the interview are summarized below.

Objections

The Specification is objected to under 35 U.S.C. § 112, 1st paragraph as failing to satisfy the written description and enablement requirements. As discussed in more detail below with respect to the 35 U.S.C. § 112 rejections, Applicant submits that the Specification satisfies the enablement requirement.

The Examiner asserts that "[t]he amendment filed 11/12/19 is objected to under 35 U.S.C. 132(a) because it introduces new matter into the disclosure. ... The added material which is not supported by the original disclosure is as follows: the substantial additions to the Summary of the Invention (~14 paragraphs); Figs. 14-33; the ne[w] paragraphs in the Detailed Description (~21 paragraphs)." *See* the final Office action, paragraph 23 bridging pages 8 and 9.

As indicated in the November 12, 2019 reply, the added material was obtained from the specification and drawings of U.S. Application No. 12/361,540 ("the '540 application"), from which the present application claims priority. *See* the Specification, page 2, 1st paragraph. According to 37 CFR 1.57(b),

> ... if all or a portion of the specification or drawing(s) is inadvertently omitted from an application, but the application contains a claim under § 1.55 for priority of a prior-filed foreign application or a claim under § 1.78 for the benefit of a prior-filed provisional, nonprovisional, international application, or international design application, that was present on the filing date of the application, and the inadvertently omitted portion of the specification or drawing(s) is completely contained in the prior-filed application, the claim under § 1.55 or 1.78 shall also be considered an incorporation by reference of the prior-filed application as to the inadvertently omitted portion of the specification or drawing(s).
>
> (1) The application must be amended to include the inadvertently omitted portion of the specification or drawing(s) within any time period set by the Office, but in no case later than the close of prosecution as defined by § 1.114(b), or abandonment of the application, whichever occurs earlier. (emphasis added)

Thus, because the added material (which is inadvertently omitted from the present application) is completely contained in the prior-filed '540 application, the priority claim in the present Specification should be considered an incorporation by reference of the '540 application. Thus, Applicant submits that the added material does not introduce new matter and should be included

in the present application. Indeed, the Examiner indicated in the February 20, 2020 interview that she would withdraw this new matter objection to the Specification once Applicant files a formal reply to the final Office action.

Accordingly, Applicant requests reconsideration and withdrawal of this objection.

Rejection under 35 U.S.C. § 101

Claims 36, 37, 39, 43-45, and 66-77 are rejected under 35 U.S.C. § 101 on the ground that the claimed invention is inoperative and lacks utility.[1]

As discussed in the interview on February 20, 2020, to overcome this rejection, the Examiner suggested that Applicant presents a declaration or a published peer-reviewed article demonstrating that the signal of Tc-99m shown in Figure 2 of the Specification was produced from the stable Mo sample.

Pursuant to the above discussion, Applicant respectfully directs the Examiner's attention to the accompanying declaration by the sole inventor Mr. A. Christian Tahan, which is submitted pursuant to 37 C.F.R. § 1.132 (referred to herein as the "Declaration"). Mr. Tahan is the sole inventor of the present '928 application and has over 25 years of experience in life and physical sciences research, including more than 20 years of experience in research and development of generating isotopes. *See* the Declaration, ¶ 3.

In the Final Office Action, the Examiner asserts that "[t]here is no known mechanism for a hydrogen-based nuclear reaction in the present invention to produce neutrons .... Simply put, it is categorically impossible for the present invention to operate as disclosed and as required by the claims to generate an isotope[]." *See* page 9, paragraph 26.

Mr. Tahan reports that the claimed invention is directed to generating a second isotope (e.g., Tc-99m) from a first isotope (e.g., Mo). *See* the Declaration, ¶ 8. Prior to the filing of the '928 application, Mr. Tahan participated in the experiment described in the paragraph bridging pages 13 and 14 of the '928 application as originally filed, which demonstrates that the claimed invention successfully achieved the above objective. *Id.* In particular, an example system of the claimed invention was used to generate isotope Tc-99m and was tested in a scintillation

[1] Applicant has cancelled claims 74 and 77. Thus, the lack of utility rejection against these two claims is now moot.

spectrometer in the cyclotron lab by Prof. John A. Correia at the Massachusetts General Hospital (MGH). *Id.*

Specifically, Mr. Tahan tested example systems of the claimed invention with one example system using a sample containing 20 mL of 96-98% sulfuric acid and 3.5 g of stable Mo powder in a graphite tube (Crucible, Saed/Manfredi G40, 1.5"OD x 1.25"ID x 3.75"DP) in the example system. *Id.*, ¶9. The stable Mo used in this experiment was obtained from Buffalo Tungsten Inc. (http://www.buffalotungsten.com/) and its composition is described in Exhibit C mentioned below. *Id.* As shown in Exhibits A and B mentioned below, stable Mo used in this experiment did not include any radioactive Mo-99, a synthetic isotope that does not occur in nature. *Id.* The sulfuric acid and the stable Mo powder were first placed into the graphite tube in the example system, which was subjected to a static magnetic field of 2000 Gs and a direct current electric field (DC electrolysis, Hewlett Packard E3631A) of 2.9 V and 5.0-5.150 A for one hour. *Id.* After the DC was turned off, the mixture containing the sulfuric acid and the Mo powder was subjected to a low frequency radio wave of 2 Hz (Vp-p ≈ 4.312-4.375 V) for one hour. *Id.* The sample (including the sulfuric acid and Mo powder) was then pipetted from the invention and collected in a VWR 20 mL tube that was closed with a screw-on top and inserted in a latex glove as a precaution against leakage by Prof. Correia in his laboratory. *Id.*

Mr. Tahan observed the testing of this sample by Prof. Correia, which was performed as follows. *Id.*, ¶10. Before testing any actual sample, Prof. Correia first performed a background test using a Canberra NaI(Tl) well-type scintillation spectrometer that contained no sample for 10 minutes to determine background or environmental detections. *Id.* The background test results were analyzed using Canberra Genie 2000 software and the radiation counts of the background are shown in Figure 1 in the Declaration, in which the x-axis is decay energy and the y-axis is the radiation counts. *Id.* Note that Figure 1 shows the radiation count over a decay energy ranging from 2.0 keV to 2048.0 keV as the top graph, and an expanded view of a decay energy region ranging from 130 to 148 keV where a characteristic Tc-99m peak is expected according to the existing literature. *Id.* As shown in Figure 1, no peak for Tc-99m is found in the background graph. *Id.*

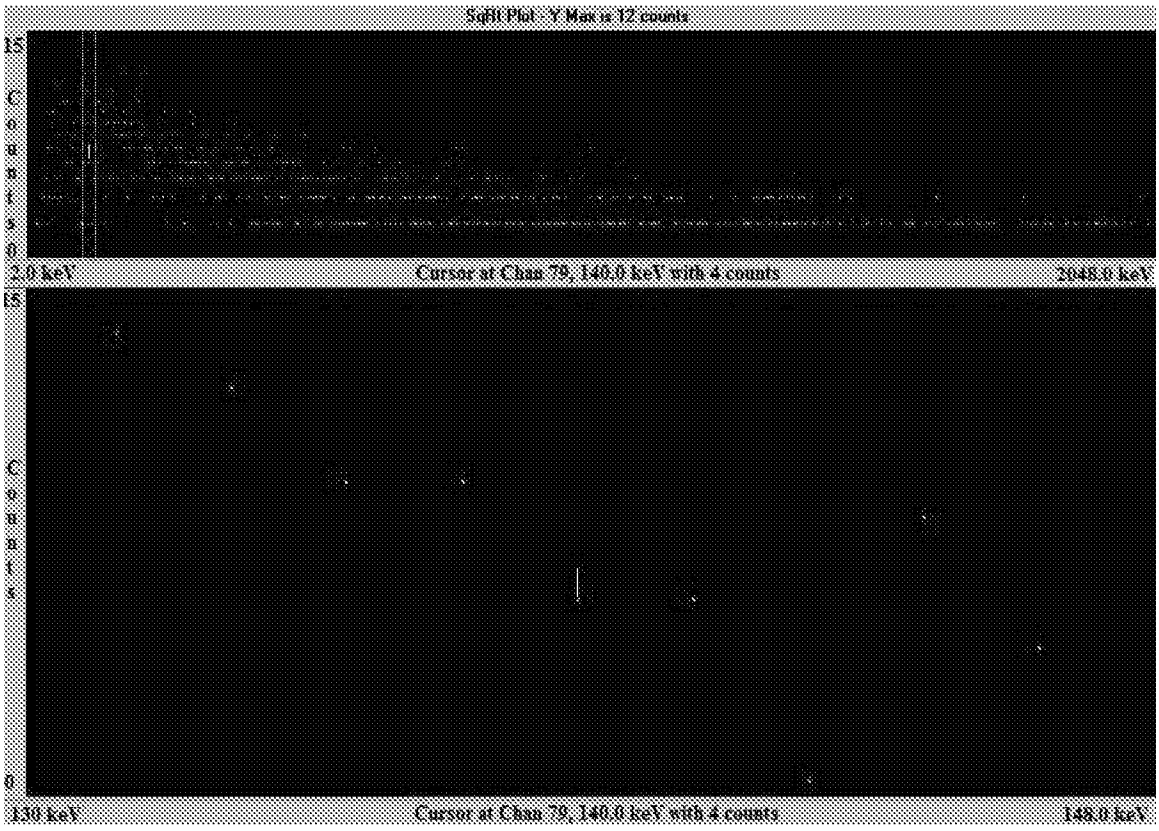

Figure 1 in the Declaration

Subsequently, a standard Tc-99m run was performed in the scintillation spectrometer using a standard Tc-99m sample that was sourced from the Department of Radiology at Massachusetts General Hospital (MGH). *Id.*, ¶*11*. The standard Tc-99m test was performed for 10 seconds. *Id.* The test results were analyzed using Canberra Genie 2000 software and the radiation counts of the standard Tc-99m sample are shown in Figure 2 in the Declaration, in which the x-axis is decay energy and the y-axis is the radiation counts. *Id.* Note that Figure 2 shows the radiation count over a decay energy ranging from 2.0 keV to 2048.0 keV as the top graph, and an expanded view of a decay energy region ranging from 112 to 166keV. *Id.* As shown in Figure 2, Tc-99m has a decay energy peak at about 141 keV. *Id.*

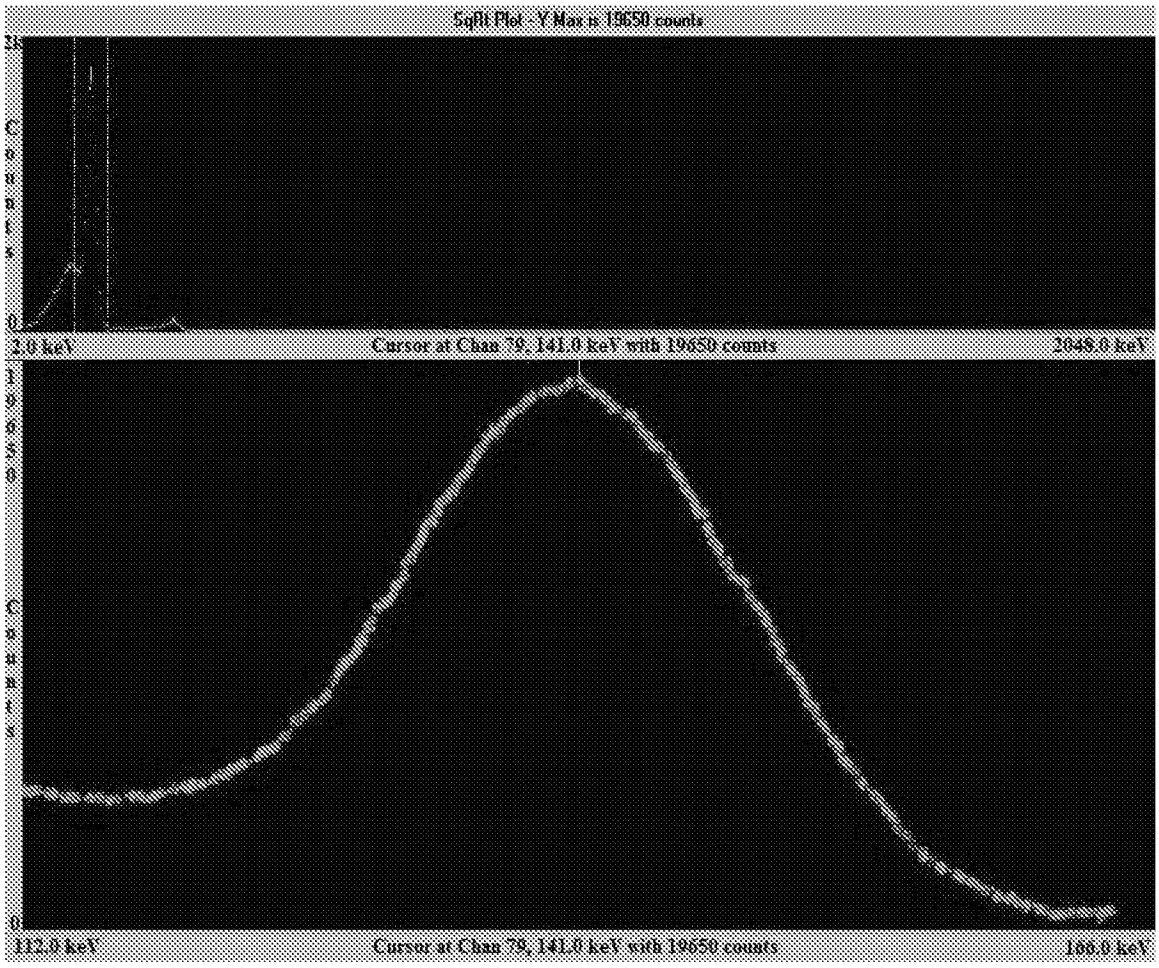

Figure 2 in the Declaration

After the standard Tc-99m test was completed, Prof. Correia placed the sample obtained from the example system described above in the scintillation spectrometer. *Id.*, ¶*12*. The scintillation spectrometer was then sealed and was used for isotope detection under the same conditions that were used to run the standard Tc-99m test. *Id.* The results from Prof. Correia's experiment are shown in Figure 2 of the '928 application, which is reproduced below. *Id.* As shown in Figure 2 of the '928 application, the sample was found to have a Curie reading of sufficient quantity to allow for the reading of approximately 141 keV, which matches the reading obtained from the standard Tc-99m test as shown in Figure 2 in the Declaration above. *Id.* Thus, the above results demonstrate that the claimed invention successfully produced isotope Tc-99m in sufficient quantity for detection. *Id.*

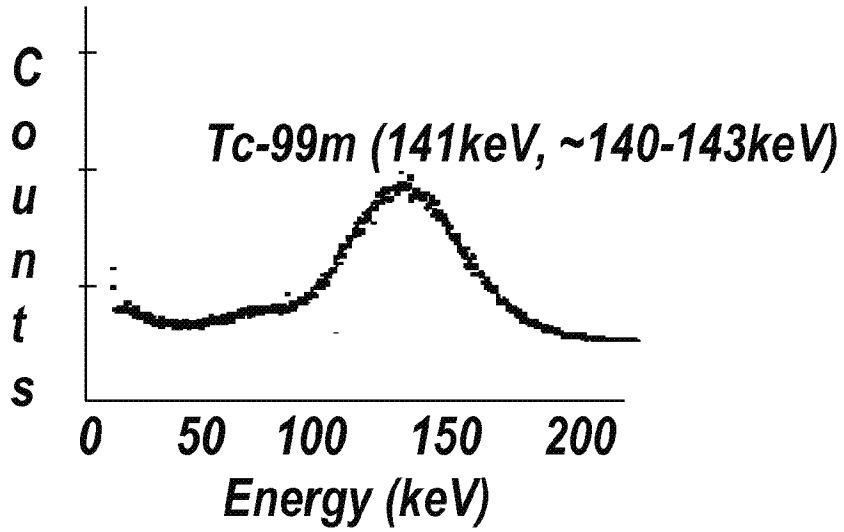

Figure 2 in the '928 application

In paragraph 6 on page 3 of the Final Office Action, the Examiner states that

> ... First of all, molybdenum is not a single isotope; it is a mixture of multiple isotopes. The specification states that "standard Mo powder" was used in experiments, but does not state the isotopic composition of this powder. In the arguments dated 08/30/17, Applicant states that the molybdenum used in the experiments is molybdenum-99. As the examiner explained in the previous office action, [molybdenum-99] spontaneously decays to Tc-99, which then also spontaneously decays to produce ionizing radiation. Accordingly, the "experimental results" purportedly illustrated in Fig. 2 are the result of measuring the spontaneous radioactive decay of Mo-99 into Tc-99 and Tc-99 into its decay products. These results would be obtained from observing *any sample of molybdenum-99*, regardless of whether the sample was subjected to the present invention. (emphasis original)

Mr. Tahan reports that, the statements made in the reply dated August 28, 2017 that molybdenum-99 (Mo-99) was used as a starting material were incorrect and would like to clarify the records as follow. *Id.*, ¶*14*. It is well known in the art that Mo-99 is a man-made isotope that does not occur in nature. *Id.* Mr. Tahan has enclosed two documents, copies of which are attached hereto as Exhibits A and B, demonstrating that Mo-99 is a synthetic isotope. *See Id.* and the highlighted portions in each document. In other words, one skilled in the art would readily understand that Mo-99 is not present in the standard Mo powder described in the Specification, which only contains naturally-occurring Mo isotopes and was purchased off the

shelf from a vendor named Buffalo Tungsten Inc. *Id.* Indeed, it is known that the majority of Mo-99 is produced in five nuclear research reactors around the world using highly enriched uranium (HEU) targets and cannot be purchased off the shelf. *See* https://en.wikipedia.org/wiki/Technetium-99m. *Id.*

Further, Mr. Tahan reports that, given that Mo-99 has a relatively short half-life (2.75 days), even if the purchased standard Mo powder includes Mo-99 when it was made (which Mr. Tahan does not concede), it would have decayed by the time Prof. Correia's experiment above was performed because the time the Mo powder spends on the shelf and during transportation would be much longer than Mo-99's half-life. *Id.*, ¶*15*. This is further supported by the Specification as filed, which states that "[t]he process, in one embodiment, can produce Technetium-99m (Tc-99m) from **stable** Molybdenum (Mo) powder." *See Id.* and the Specification, page 2, 2nd paragraph; emphasis added. Mo-99 is certainly not a stable Mo isotope. *Id.*

In addition, Mr. Tahan has enclosed a certificate of analysis (a copy of which is attached hereto as Exhibit C) of the standard Mo powder purchased from Buffalo Tungsten Inc., which shows that it does not contain Tc. *Id.*, ¶*16*. Figure 2 of the present application shows that Prof. Correia's experiment described above demonstrates that Tc-99m (an isotope that was not in the stable Mo powder used in the above experiment) was formed from a stable Mo powder that does not contain Mo-99. *Id.* In other words, the Specification provides experimental results demonstrating that a claimed system was able to convert one isotope (e.g., a stable Mo powder which does not contain Mo-99) to another isotope (e.g., Tc-99m). *Id.* Tc-99m is a well-known radioactive isotope used in tens of millions of medical diagnostic procedures annually. *Id.* Thus, Mr. Tahan is of the opinion that the claimed system is operative and has utility. *Id.*

The Examiner states at paragraph 20 on page 8 of the Final Office Action that "[a] scintillation counter is incapable of providing any indication of the source of ionization radiation", that "[i]t is also impossible to determine the elemental make-up of a sample using a scintillation counter," and that "[t]he results of Figure 2 therefore indicate only that the scintillation counter of the experiment was exposed to ionization radiation." Mr. Tahan reports that these statements are incorrect because a scintillation detector or spectrometer reports specific energy for radiation from decay that corresponds to particular isotopes. *Id.*, ¶*17*. In this case,

Figure 2 of the present '928 application shows that decay energy of about 141 keV was detected by the scintillation detector. *Id.* As mentioned above, this decay energy corresponds to the energy output of radioactive isotope Tc-99m. *Id.* In other words, contrary to the Examiner's assertions, the scintillation detector was able to determine the elemental make-up of a sample and, in this case, was able to detect Tc-99m produced by the claimed invention. *Id.*

The Examiner states in paragraph 20 on page 8 of the Final Office Action that "there is no description of experimental conditions that include a negative control experiment, so it cannot be ruled out that the 'results' of Figure 2 are due simply to the presence of background/environmental radiation." However, as mentioned above, Mr. Tahan reports that a separate background run of the claimed system (i.e., a negative control) was made to eliminate the possibility of a background reading. *Id.*, ¶*18*. In addition, Mr. Tahan reports that one skilled in the art would readily understand that no background or environmental source would produce the specific reading (i.e., 141 keV) for Tc-99m, which is an isotope not found naturally in the environment, particularly due to its relatively short half-life (i.e., about 6 hours). *Id.* Thus, Mr. Tahan reports that, even in the absence of any negative control experiment, one skilled in the art would still understand that the Tc-99m must be produced by the claimed system in view of the results shown in Figure 2 of the '928 application. *Id.*

The Examiner states in paragraph 22 on page 8 of the Final Office Action that

> … any sample of molybdenum-99 will exhibit ionizing radiation, regardless of whether it is placed in the present invention. Molybdenum-99 spontaneously undergoes radioactive beta decay with a half-life of 66 hours into technetium-99, which then undergoes gamma decay (i.e., releases ionizing radiation). Accordingly, a scintillation counter exposed to a sample of molybdenum-99 will always detect ionizing radiation, because natural radioactive decay processes produce this effect. No human intervention whatsoever would be required to detect ionizing radiation from a sample of molybdenum-99 using a scintillation counter.

However, Mr. Tahan reports that, as mentioned above, stable Mo powder, which did not include radioactive Mo-99, was used as the initial isotopes placed into the claimed system that resulted in Figure 2 of the '928 application. *Id.*, ¶*19*. Indeed, Mo-99 is not a stable Mo isotope due to its relatively short half-life (i.e., about 2.75 days). *Id.* In addition, as also discussed above, the decay energy shown in Figure 2 of the '928 application corresponds to the energy released by

radioactive isotope Tc-99m. *Id.* Indeed, it is well known in the art that Mo-99 has a decay energy of about 1.357 MeV (i.e., 1357 keV). *Id.* In other words, Mr. Tahan reports that, based on the Specification, one skilled in the art would readily understand that the decay energy in Figure 2 of the '928 application was from Tc-99m, particularly when compared with the results obtained from the standard Tc-99m test described above. *Id.* In sum, Mr. Tahan reports that, because the stable Mo introduced into the claimed system did not include Mo-99, one skilled in the art would understand that Tc-99m would not have been produced in the absence of the inventive system. *Id.* Thus, Mr. Tahan reports that the presence of Tc-99m in the claimed system as indicated by Figure 2 of the '928 application is evidence of the operability of the system, which converts one isotope (e.g., stable Mo) to another isotope (e.g., Tc-99m). *Id.* Additionally, Mr. Tahan reports that one skilled in the art would understand that Figure 2 of the Specification also provides evidence that Mo-99 was produced by the system of the invention since the decay of Mo-99 to Tc-99m is the reason for the Tc-99m detections. *Id.* In other words, Tahan reports that one would understand that Mo-99 (an isotope not in the starting stable Mo powder) was necessarily produced by the inventive system from the stable Mo powder. *Id.*

Thus, for at least the same reasons set forth above, claims 36, 37, 39, 43-45, and 66-77 possess utility.

Rejections under 35 U.S.C. § 112

Claims 36, 37, 39, 43-45, and 66-77 are rejected under 35 U.S.C. § 112 on two grounds, each of which is traversed below:[2]

I

Claims 36, 37, 39, 43-45, and 66-77 are rejected under 35 U.S.C. § 112(a) or 35 U.S.C. § 112 (pre-AIA), 1st paragraph, as failing to comply with the enablement requirement.

The Examiner states that "[t]he instant disclosure does not demonstrate that the inventor has successfully operated the present invention and therefore does not provide a framework which one of ordinary skill in the art could use to also make and use the present invention." *See* the final Office action, page 10, paragraph 29.

[2] Applicant has cancelled claims 74 and 77. Thus, the lack of enablement rejection and the indefiniteness rejection against these two claims are now moot.

As discussed above, the rejected claims are directed to a system for generating an isotope and the Specification has provide sufficient description how to make and use a claimed system to convert one isotope (e.g., stable Mo powder which does not contain Mo-99) to another isotope (e.g., Mo-99 or Tc-99m). Thus, the rejected claims are fully enabled by the Specification as originally filed.

Accordingly, Applicant requests reconsideration and withdrawal of this rejection.

II

Claims 36, 37, 39, 43-45, and 66-77 are rejected under 35 U.S.C. § 112(b) or 35 U.S.C. § 112 (pre-AIA), 2nd paragraph, as indefinite.

The Examiner asserts that "[c]laim 36 refers to 'an isotope' in the preamble, then 'a first isotope' in line 5. There is insufficient antecedent basis in claim 36 for 'the second isotope' recited in line 16 ('capable of converting the first isotope to the second isotope') and it is unclear whether the isotope of the preamble is one of the isotopes referred to in the body of the claim." *See* the final Office action, page 12, paragraph 33.

Applicant has replaced "the second isotope" recited in claim 36 with "a second isotope" to obviate this rejection. Note that, in view of the language "converting the first isotope to a second isotope" recited in this claim, one skilled in the art would readily understand that the second isotope is the isotope generated and therefore would understand that the isotope mentioned in the preamble "a system for generating an isotope" refers to the second isotope. Indeed, the Examiner agreed in the February 20, 2020 interview that Applicant's proposed claim amendment above would overcome this indefiniteness rejection.

Accordingly, Applicant requests reconsideration and withdrawal of this rejection.

Rejections under 35 U.S.C. §102 and §103

Claims 36, 37, 66, 67, 72, 73, 75, and 76 are rejected under pre-AIA 35 U.S.C. § 102(b) as anticipated by Eccles, U.S. Application Publication No. 2005/0236376 ("Eccles"). Claims 39,

43, 44, and 68-70 are rejected under pre-AIA 35 U.S.C. §103 as obvious from Eccles in view of Jouanneau, U.S. Application Publication No. 2006/0088138 ("Jouanneau").[3]

Applicant does not concede the propriety of these rejections. However, to expedite prosecution, Applicant has incorporated claims 77 and 74 into claims 36 and 66, respectively, to obviate these rejections. Since claims 74 and 77 are not subject to the above rejections, Applicant submits that the amended claims are novel and nonobvious over the cited references. Indeed, the Examiner agreed in the February 20, 2020 interview that Applicant's proposed claim amendment above would overcome the anticipation and obviousness rejections.

Accordingly, Applicant requests reconsideration and withdrawal of these rejections.

Conclusions

Applicant submits that this application is now in condition for allowance, which action is respectfully requested.

Any circumstance in which Applicant has: (a) addressed certain comments of the Examiner does not mean that Applicant concedes other comments of the Examiner; (b) made arguments for the patentability of some claims does not mean that there are no other good reasons for the patentability of those claims and other claims; or (c) amended a claim does not mean that Applicant concedes any of the Examiner's positions with respect to that claim or other claims.

This document is filed concurrently with a Request for Continued Examination ("RCE"). The $950.00 fee for the RCE is being paid concurrently herewith on the Electronic Filing System (EFS) by way of Deposit Account authorization.

[3] Applicant has cancelled claims 74 and 77. Thus, the anticipation and obviousness rejections against these two claims are now moot.

Apply the above fee and any other necessary charges or credits to Deposit Account 06-1050, referencing the above attorney docket number.

Respectfully submitted,

Date: July 1, 2020

/Tony Zhang/

Tony Zhang
Reg. No. 69,057

Customer Number 26161
Fish & Richardson P.C.
Telephone: (212) 641-2279
Facsimile: (877) 769-7945

23997830.doc

EXHIBIT A

Periodic Table of Elements

Mo - Molybdenum

Molybdenum Menu

Nuclides / Isotopes

Nuc-lide	Atomic Mass	NN	Abun %	Spin	Half Life	DM	DT	BR %	Decay Energy (MeV)
Mo83	82.949	41	Syn						
Mo84	83.94	42	Syn	0+	>150ns	ε	Nb84		6.100
Mo85	84.937	43	Syn		>150ns				
Mo86	85.931	44	Syn	0+	19.6s	ε	Nb86		5.300
Mo87	86.927	45	Syn	7/2+	13.4s	ε + P	Zr86	>0	2.820
					13.4s	ε	Nb87		6.490
Mo88	87.922	46	Syn	0+	8m	ε	Nb88		3.720
Mo89	88.9195	47	Syn	9/2+	2.04m	ε	Nb89		5.580
meta state 0.387MeV			Syn	1/2-	190ms	IT			0.387
Mo90	89.9139	48	Syn	0+	5.56h	ε	Nb90		2.489
Mo91	90.9118	49	Syn	9/2+	15.49m	ε	Nb91		4.434
meta state 0.653MeV			Syn	1/2-	65s	IT		50.1	0.653
					65s	ε	Nb91	49.9	5.087
Mo92	91.9068	50	14.84	0+	**Stable**				
Mo93	92.9068	51	Syn	5/2+	4000y	ε	Nb93		0.405
meta state 2.424MeV			Syn	21/2+	6.85h	IT		99.88	2.425
					6.85h	ε	Nb93	0.12	2.830
Mo94	93.9051	52	9.25	0+	**Stable**				
Mo95	94.9058	53	15.92	5/2+	**Stable**				
Mo96	95.9047	54	16.68	0+	**Stable**				
Mo97	96.906	55	9.55	5/2+	**Stable**				
Mo98	97.9054	56	24.13	0+	**Stable**				
Mo99	98.9077	57	Syn	1/2+	65.94h	β^-	Tc99m		1.357
Mo100	99.9075	58	9.63	0+	1.00E ^{19}y	β^-	Ru100		3.034
Mo101	100.9104	59	Syn	1/2+	14.61m	β^-	Tc101		2.824
Mo102	101.9103	60	Syn	0+	11.3m	β^-	Tc102		1.010
Mo103	102.9132	61	Syn	3/2+	67.5s	β^-	Tc103		3.750
Mo104	103.9138	62	Syn	0+	60s	β^-	Tc104		2.160
Mo105	104.917	63	Syn	5/2-	35.6s	β^-	Tc105		4.950
Mo106	105.9181	64	Syn	0+	8.4s	β^-	Tc106		3.520
Mo107	106.922	65	Syn		3.5s	β^-	Tc107		6.160
Mo108	107.924	66	Syn	0+	1.09s	β^-	Tc108		4.640
Mo109	108.928	67	Syn		0.53s	β^-	Tc109		7.500
Mo110	109.93	68	Syn	0+	0.3s	β^-	Tc110		5.900
Mo111	110.935	69	Syn		>150ns				
Mo112	111.937	70	Syn	0+	>150ns				
Mo113	112.942	71	Syn		>150ns				

Nuclide	Potential Parent Nuclides
Mo83	None known
Mo84	None known
Mo85	None known
Mo86	None known
Mo87	None known
Mo88	Tc88 (Syn) Tc88m (Syn)

Mo89	Tc89 (Syn) Tc89m (Syn)
meta state 0.387MeV	None known
Mo90	Ru91m (Syn) Tc90 (Syn) Tc90m (Syn)
Mo91	Tc91 (Syn) Tc91m (Syn)
meta state 0.653MeV	None known
Mo92	Nb92 (Syn) Ru93m (Syn) Tc92 (Syn)
Mo93	Tc93 (Syn) Tc93m (Syn)
meta state 2.424MeV	None known
Mo94	Nb94 (Syn) Nb94m (Syn) Tc94 (Syn) Tc94m (Syn)
Mo95	Nb95 (Syn) Nb95m (Syn) Tc95 (Syn) Tc95m (Syn)
Mo96	Nb96 (Syn) Tc96 (Syn) Tc96m (Syn) Zr96 (Natural)
Mo97	Nb97 (Syn) Tc97 (Syn) Tc97m (Syn)
Mo98	Nb98 (Syn) Nb98m (Syn)
Mo99	Nb99 (Syn) Nb99m (Syn)
Mo100	Nb100 (Syn) Nb100m (Syn) Tc100 (Syn)
Mo101	Nb101 (Syn)
Mo102	Nb102 (Syn) Nb102m (Syn)
Mo103	Nb103 (Syn) Nb104 (Syn)
Mo104	Nb104 (Syn) Nb104m (Syn)
Mo105	Nb105 (Syn)
Mo106	Nb106 (Syn)
Mo107	Nb107 (Syn)
Mo108	Nb109 (Syn)
Mo109	Nb109 (Syn) Nb110 (Syn)
Mo110	Nb110 (Syn)
Mo111	None known
Mo112	None known
Mo113	None known

Key:

- **NN** = Number of Neutrons
- **Abun %** = Natural Abundance (as a percentage)
- **Syn** = Synthetic Nuclide (does not occur in nature)
- **DM** = Decay Mode
  - α = Alpha emission
  - β^- = Beta emission
  - $\beta^- \beta^-$ = Double beta decay
  - β^+ = Positron emission
  - ε = Electron Capture
  - IT = Isomeric Transition
  - N = Neutron emission
  - P = Proton emission
  - SF = Spontaneous Fission
- **DT** = Decays To
- **BR %** = Branch Ratio (as a percentage)

Molybdenum Menu

References

A list of reference sources used to compile the data provided on our periodic table of elements can be found on the main periodic table page.

Citing this page

If you need to cite this page, you can copy this text:

Kenneth Barbalace. Periodic Table of Elements - Mo - Molybdenum. EnvironmentalChemistry.com. 1995 - 2020. Accessed on-line: 1/31/2020 https://EnvironmentalChemistry.com/yogi/periodic/Mo-pg2.html

EXHIBIT B

TABLE 2
Atomic Properties of Molybdenum

Atomic number	42
Isotopes	
Natural	92,94,95,96,97,98,100
Artificial	90,91,93,99,101,102,105
Atomic weight	95.95
Atomic radius, coordination number 8	1.36 Å
Ionic radius	
Trivalent	0.92 Å
Sexivalent	0.62
Atomic volume	9.41 cm^3/g-atm
Lattice type	Body-centered cubic
Thermal-neutron data	
Nuclei per unit volume	0.0640×10^{24}/cm^3
Cosine scattering angle	0.9931
Average logarithmic energy	
Decrement (ξ)	0.0207
2200 m/s cross-sections	
Microscopic	
Absorption (σa)	2.5 barns
Scattering (σs)	7 barns
Total (σt)	9.5 barns
Macroscopic	
Absorption (Σa)	0.160 cm^{-1}
Scattering (Σs)	0.448 cm^{-1}
Total (Σt)	0.608 cm^{-1}
Mean free path	
Absorption (λa)	6.25 cm
Scattering (λs)	2.23 barns
Total (λt)	1.64 barns
Fast-neutron-absorption cross-section	
10/250 keV	9
1230	6
Ionization potential	7.2 eV
Apparent positive-ion work function	8.6 eV
Apparent electron work function	4.2 eV

TABLE 3
Thermal Properties of Molybdenum

Melting point	2610°C
Heat of fusion (estimated)	6.7 kcal/mol
Boiling point	5560°C
Heat of vaporization	117.4 kcal/mol
Heat content (298.16—1800°K), cal/mol	$H_T - H_{298.16} = 5.548\ T + 0.65 \times 10^{-3}\ T^2 - 1692$
Heat capacity (298.16—1800°K) cal/°mol	$C_p = 5.48 + 1.30 \times 10^{-3}\ T$
Entropy (crystals)	$S^\circ_{298.16} = 6.83$ cal/°mol
Vapor pressure (°C)	
1727	3.9×10^{-10} atm
2610	1.7×10^{-5}
4727	1.8×10^{-1}
5560	1.0

TABLE 4
Electrical and Magnetic Properties of M

Electrical conductivity at 0°C	34%
Electrical resistivity	See
Hall constant (work hardened)	+17
Lorenz constant	2.72
Hydrogen overpotential (1×10^{-3} amp/cm^2)	0.44
Electrochemical equivalent (sexivalent)	0.16
Minimum arcing voltage	17 V
Minimum arcing amperage	
24 V line voltage	10 A
110	1.5
220	1.0
Magnetic susceptibility (X)	
25°C	0.9
1825°	1.1
Paramagnetic	

TABLE 5
Optical and Emissivity Properties of

Optical reflectivity	
5,000 Å	46%
10,000 Å	93
Total optical emissivity (°C)	
1,000	0.13
1,500	0.19
2,000	0.24
Total normal emissivity	See F
Thermionic emission in high vacuum (°C)	
1,600	Abou
2,000	85
Spectral emissivity	
3,900 Å	Abou
6,700 Å	0.40
Radiation for 5500 Å at 20°C	54%
Total radiation (°C)	
527	Abou
1,127	3.0
1,727	19
2,327	68

TABLE 6
Some Miscellaneous Properties of M

Density	
Coefficient of friction	
Compressibility at 293°C	
Surface tension at melting point	
Dynamic modulus of rigidity	
Dynamic Young's modulus of elasticity	
Dynamic Poisson's ratio	
Static modulus of elasticity	

EXHIBIT C

CERTIFICATE OF ANALYSIS:

TO:

Date:

Quantity:

Customer's Order No:

P/N:

TYLER SHOWALTER
Quality Control Manager

LOT NO: M02075-3

MATERIAL: MOLYBDENUM POWDER

CHEMICAL and SPECTROGRAPHIC

ELEM.	%	ELEM.	%
Al	<0.001	NH_3	
As		Na	<0.001
Bi		Ni	0.0015
C_T	<0.001	O/LOR	0.056
C_F		P	
Ca	0.001	Pb	<0.001
Cb		S	
Co	<0.001	Sb	
Cr	<0.001	Si	<0.001
Cu	<0.001	Sn	<0.001
Fe	0.002	Ta	<0.001
K	0.0015	Th	
Mg	<0.001	Ti	<0.001
Mn	<0.001	W	<0.015
Mo	99.9	V	
N		Zr	<0.001

PHYSICAL

Fisher No.	As Supplied	Lab. Milled
Av. Microns	4.72	4.54
Porosity	.610	.497
Scott Density	29.0	gm/cu. in.
Tap Test		gm/cc.

PARTICLE SIZE DISTIBUTION BY SEDIGRAPH

Micron Range	Wt. %	Micron Range	Wt. %
0-2	1	7-8	6
2-3	7	8-9	4
3-4	9	9-10	5
4-5	8	10-15	18
5-6	7	15-20	14
6-7	6	>20	19

SCREEN ANALYSIS

MESH SIZE	Wt. %
-200	ALL