新加坡证道学学会
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Occultism and the atom: the curious story of isotopes

奥义主义与原子：同位素的神奇故事

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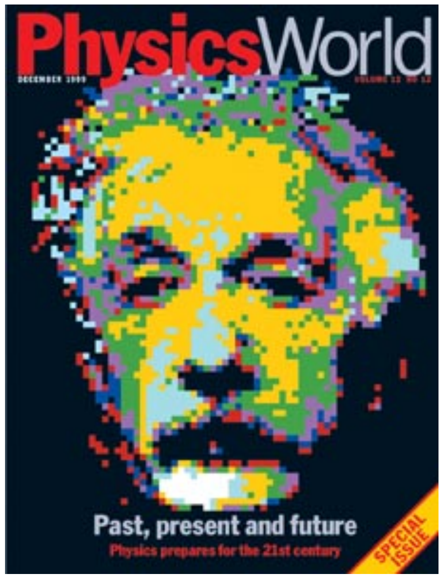

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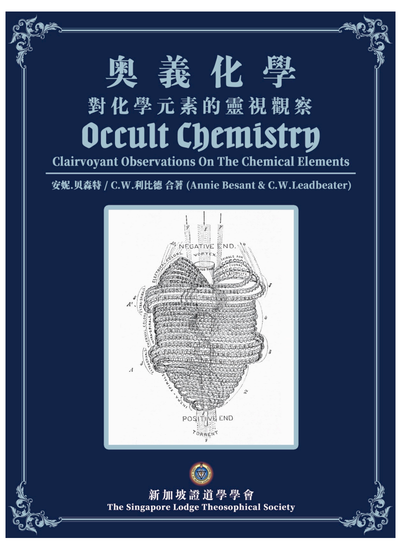


《奥义化学》Occult Chemistry
安妮.贝森特与利比德合著|首次在 1895 年以文章形式发表|1908 年成书

正文

当弗朗西斯·阿斯顿（Francis Aston）在 1913 年发现一种新型氖元素时，他最初将其与两位“奥义化学家”通过一种奇特的灵视力看到的原子联系起来。但为什么这段历史后来被改写了呢？

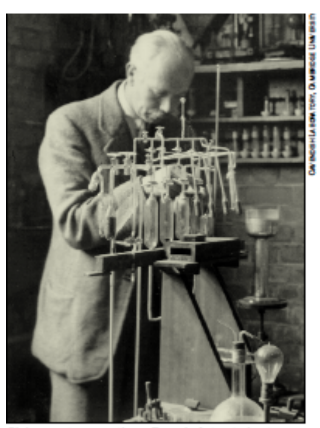
奥义科学：内幕

历史学家和科学家一样，有时会有偶然的发现，从而开辟出新的研究领域。当我在剑桥大学图书馆翻阅一大箱灰色的阿斯顿论文时，我发现了阿斯顿、元粒子和证道学的故事，这是我研究两次大战之间核物理学历史的一部分（《物理世界》2000 年 7 月，第 43-48 页）。这些论文没有编目，主要是阿斯顿发表的许多论文的印刷品，还有一些科研同事写给他的有趣信件和他的几本实验室笔记。在这些资料中，有一份发黄的 15 页打字手稿，题为“论大气氖的均质性”。

这份文件的前几页留下了烟斗灰灼烧过的痕迹，没有注明日期，也与阿斯顿发表的任何论文不符。但根据文件中对他在氖和元氖的阳极射线分析方面工作的描述，以及他所引用的其他论文的内部证据，很快就可以确定该文件写于 1913 年下半年。这似乎很可能是阿斯顿在 1913 年 9 月于伯明翰举行的英国协会会议上发表的论文的一个版本，我知道他曾在那次会议上就他的氖发现发表过演讲。

这份文件不仅揭示了阿斯顿试图分离两种形式的氖的重要新细节，还表明他与玻尔保持着联系，后者告诉他新的原子核理论及其对解释氖和元氖的影响。但是，在论文的最后一页——在通常的致谢等内容之后——有一个奇怪的“关于‘元氖’名称的说明”，阿斯顿在其中解释了这个名称的来源。

起初，我对他竟然熟悉贝森特和利比德的《奥义化学》（Occult Chemistry）感到惊讶，但随后便产生了兴趣，并决定追寻与证道学的联系。关于阿斯顿时代的文化以及他取得成果的方式的故事开始浮出水面，这与我读过的历史书籍和文章中的故事大相径庭。很明显，历史是从后来的角度改写的。面对这一挑战，我决定写一本关于阿斯顿、同位素和质谱仪真实历史的书。这篇文章只是这个故事的一小部分。



Clairvoyant connection – Francis Aston trying to separate neon and "meta-neon" in about 1913.

与灵视的联系——弗朗西斯·阿斯顿在 1913 年左右试图将氖气和“元氖”区分开来

科学发现的道路有时很奇特。我们都熟悉牛顿和苹果落地的故事，或者弗里德里希·凯库勒（Friedrich Kekulé）梦见蛇咬自己的尾巴、从而发现苯环状结构的事迹。但是，这些故事虽然引人入胜，却往往充满传说色彩。它们在科学中发挥着作用，强调个人心理和英雄式科学天才的灵感闪光，而不是科学工作中更为常规和集体的方面。

然而，撇开浪漫主义不谈，科学史 —— 就像奥威尔（Orwell）笔下的“老大哥”国家—— 通常会书写和改写历史，删除不便提及的事实、错误和特质，只留下一条通往我们现有知识的合理化道路，或历史学家有时称之为“辉格”史。这种做法不仅歪曲了历史事件的实际进程，而且对科学活动的丰富性、以及科学与更广泛文化间的互动作了过于简单化的描述，从而产生误导。

例如，在物理学史中，弗雷德里克·索迪（Frederick Soddy）和弗朗西斯·阿斯顿（Francis Aston）发现同位素通常被视为原子和核物理单一线性式发现的一部分。我们被告知，这个故事始于 19 世纪 90 年代对放射性的发现，接着是原子核（1911 年）、同位素（1913 年）、波动力学（1920 年代）和中子（1932 年）的发现，然后是核裂变（1938 年），最终是原子弹（1945 年）。

这个以原子弹为导向的故事自然强调了原子武器的关键科学要素。 但在这样做的过程中，它过分合理化了这些发现的实现方式，并对科学发现的过程和科学发展的原因作了欺骗性的描述。如果我们不事后诸葛亮般地审视事件的实际过程，就会发现事实有时确实比虚构更离奇。

J·J·汤姆森（J J Thomson）和“阳极射线” （positive rays）

对于物理科学来说，19 世纪 90 年代是令人震惊的年代。稀有气体、X 射线、放射性和泽曼效应（Zeeman effect）的发现，以及离子理论和物质电理论的阐述，从根本上改变了我们对物理世界的认识。在剑桥的卡文迪什实验室，J·J·汤姆森于 1897 年发现了构成阴极射线的“粒子”——即后来被称为电子的粒子——开创了原子的微观物理学。然而，当公众惊叹于新奇的 X 射线摄影技术时，汤姆森和他的学生以及其他物理学家已经开始了探索原子和辐射本质的挑战。

汤姆森花了数年时间，试图从电子出发研究出一套原子结构方案。他尝试归纳各种原子内部的电子团旋转排列，希望找到一种解释原子物理和化学特性的方法。但是，尽管他很好地理解了负电的性质，即电子团的旋转环，但他对中性原子中必然存在的与之抗衡的“正电性”感到迷惑不解。汤姆森认为，正电性或多或少是一种无质量的粘合剂，将电子团以及原子固定在一起。起初，他认为原子中的电子团数必须与原子质量数大致相同。散射和其他实验很快使他减少了模型中的电子团数量，但这使其辐射不稳定。汤姆森得出结论，正电性的载体粒子必须有质量——而且它确实必须包含原子的大部分质量。

因此，汤姆森在 1906 年开始了一项关于“阳极射线”的新研究项目——通过

气体放电管阴极上的一个小孔射出的离子——试图了解正电性及其在原子结构中的作用。 汤姆森主要通过他的助手埃比尼泽·埃弗雷特（Ebenezer Everett）和他的学生乔治·凯伊（George Kaye）——凯伊后来与拉比（Laby）共同撰写了著名的《物理和化学常数表》（Tables of Physical and Chemical Constants） ——汤姆森修改了他十年前在成功的阴极射线实验中使用的技术。通过在放电管周围布置电场和磁场，他能够将阳极射线引导到一个小型荧光屏上。理论上，射线应该在荧光屏上形成一系列抛物线，每条抛物线由具有相同电荷质量比（e/m）但速度不同的粒子束形成。

然而，在实际操作中，实验却遇到了很大的麻烦。实验结果对气压的变化非常敏感，要达到低压尤其困难。无论试管中的气体是什么，粒子的电荷质量比（e/m）最大值始终是氢离子 H^+ 电荷质量比最大值。据此汤姆逊得出结论：H^+是所有原子的基本成分。然而除此以外，实验很难有一致的意义，到 1909 年，实验陷入了僵局。更糟糕的是，凯伊于次年离开卡文迪什，前往国家物理实验室工作，这让汤姆森陷入了困境。

他开始四处寻找新助手。幸运的是，他听取了伯明翰大学好友约翰·亨利·坡印廷（John Henry Poynting）的建议，把这个职位给了坡印廷以前的学生之一——弗朗西斯·威廉·阿斯顿（Francis William Aston）。阿斯顿从小就喜欢烟火和机械，19 世纪 90 年代中期曾在梅森学院（Mason College，即伯明翰大学的前身）学习化学和物理。他在玻璃吹制和工具使用方面极为娴熟，并在家中的阁楼上建立了自己的工作室和实验室。轰动一时的 X 射线发现令他着迷，在伍尔弗汉普顿（Wolverhampton）一家酿酒厂工作之余，他把大部分业余时间都花在了设计和制造自己的气体放电装置和气泵上。1903 年，坡印廷为阿斯顿提供了奖学金，让他重返伯明翰大学，在接下来的几年里，他一直在那里自由地从事气体放电研究工作。

荒诞的怪物

1910 年，阿斯顿来到卡文迪什，极大地改变了汤姆森的实验方法。阿斯顿是一位能通过系统性、渐进性提高从仪器中获得最佳效果的专家，他找到了在比汤姆森以前所能达到的更低压力下实现和工作的方法。现在，不同气体的原子和分子抛物线特征首次变得清晰可见，阿斯顿引入了摄影方法来检测和记录它们。汤姆逊开始意识到，阳极射线仪器可以用来识别气体及其成分，到 1912 年，他和阿斯顿开始推广“阳极射线频谱仪”，将其作为一种化学分析方法。

阿斯顿在继续修改和完善这项技术的同时，还开始使用新方法对气体进行系统的研究。与汤姆森一样，他也认为气体放电的低压条件是进一步研究异常现象的富饶源泉。他写道：“我们不需要为[照相]底片上发现了与既不在天上也不在地下的分子相对应的线条而感到惊讶；我们这些化学家也不需要对分子世界中诸如 H^3、CH、CH^2、CH^3、N^3 等这些不自然和荒诞的怪物感到恐惧。相反，我们应该把这一研究方向作为一个极有希望的领域来研究化合物解离、电离和化学作用的实际机理。”

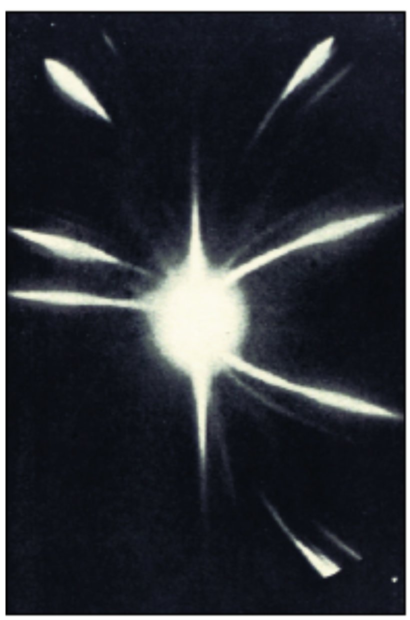
这是对阳极射线实验意义的重大改变。它们不再仅仅是研究正电性的一种物理

方法，也是发现新化学现象的一种手段——或许还是理解物理和化学的一种通俗方法。1911 年，研究的新方向取得了成果，汤姆森注意到一条与原子质量 3 相对应的线，这条线时隐时现，他形容它“就像海蛇一样难以捉摸”。他将其命名为“X3”，并在接下来的几年中花费了大量时间来追寻这个怪物。

1912 年，当阿斯顿将氖气引入电子管时，他发现了自己的“怪物”。当时，像氖这样的稀有气体还比较新奇，难以获得，人们对它的了解也不多。尽管当时氖的原子量刚被确定为 20.2，但它的性质仍然是个谜。当阿斯顿在阳极射线摄谱仪中分析氖时，他不仅看到了与原子质量约为 20 相对应的预期抛物线，而且还看到了与原子质量为 22 相对应的持续 “阴影”抛物线。

阿斯顿认为他发现了一种与氖密切相关的新元素——也许是一种新的稀有气体或至少一种稀有气体的新特征。他将这种新元素命名为“元氖”（meta-neon）。正是在这里，阿斯顿与奥义学的联系首次浮出水面。1913 年，阿斯顿在伯明翰举行的英国协会（British Association ，BA）年会上宣布了他的发现，在论文的脚注中，他提到了安妮·贝桑特（Annie Besant）和查尔斯·利比德（Charles Leadbeater）1908 年出版的《奥义化学：对化学元素的一系列灵视观察》（*Occult Chemistry: A Series of Clairvoyant Observations on the Chemical Elements*）。

阿斯顿指出：“[作者]声称，他们通过物理学学生完全无法理解的证道学方法，确定了所有已知元素和几种当时未知元素的原子量。其中有一种元素的原子量为 22.33（H = 1），他们称之为‘元氖’。 我们对这种新气体的性质知之甚少，因此我在本文中使用了这个名称。”



鬼影？——阿斯顿的阳极射线频谱仪拍摄的氖和元氖（右上角）

星光界视力

证道学——字面意义为“神圣的智慧”（译者注：证道学英文 theo-和-sophy 两词根涵义分别是神与智慧）——是一个古老的的哲学和宗教信仰体系，涉及神圣的本质和过程及其与现象宇宙的关系。现代形式的有组织的证道学是 19 世纪 70 年代在美国创立的一场社会和思想运动，从 19 世纪 80 年代开始在英国和欧洲流行。作为有组织的宗教和科学理性主义的替代品，证道学是这一时期崛起的众多信仰体系之一，它借鉴了东方哲学、神秘主义和可追溯到毕达哥拉斯的古老奥义主义传统思想。 它融合了奥义智慧和灵魂哲学（包括转世信仰)，填补了维多利亚时代人们对现代科学唯物主义和基督教的失望情绪（他们认为基督教已经受到科学的损害)。特别是，证道学强调奥义的智慧，这使它对知识分子具有强大的吸引力。他们认为，在一个日益物质化、缺乏道德或精神价值的世界中，证道学是一种探索和表达隐秘的真实世界法则的方式。

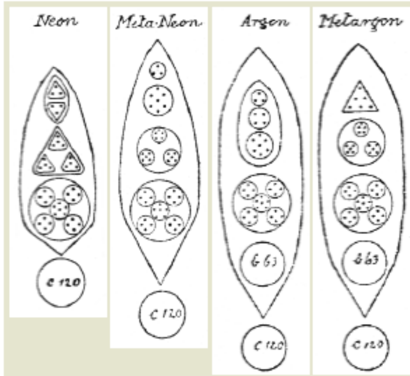
当然，众所周知，这一时期英国的几位著名物理学家——包括雷利勋爵（Lord Rayleigh)、奥利弗·洛奇（Oliver Lodge）和汤姆森本人——都是心灵研究学会（Society for Psychical Research）的成员，并对我们现在所说的超自然现象感兴趣。尽管他们的立场各不相同，有的完全相信，有的谨慎怀疑，但他们都希望物理学能够揭示正常经验范围之外的现象。与灵学研究和通灵主义一样，证道学在 20 世纪初也是一种既有争议又很时髦的思想。

阿斯顿在 1913 年英国科学院会议上提到的贝森特和利比德是英国证道学的两位领军人物。 他们对证道学理论和公众传播做出了重大贡献。他们在 1905 年出版的《思想形状》(Thought Forms）一书图文并茂地研究了与不同情绪和情感相关的“星光”环，该书被广泛阅读，并对包括蒙德里安（Mondrian)、康定斯基（Kandinsky）和勋伯格（Schoenberg）在内的许多艺术家和音乐家产生了深远影响。贝森特和利比德认为证道学是一种更高级形式的科学——通过它可以揭示和检验物理科学无法获得（或忽视）的自然现象和洞察力，并通过它可以获得更深层次的普世真理。从这个意义上说，他们认为证道学和科学是相辅相成的。

1895 年夏天，利比德首次利用一种被他称为“星光视觉”的灵视力，“看到了”氢、氮和氧原子的内部。他对各种元素原子内部结构的描述被转录下来，并于 1895 年 11 月以“奥义化学”为题首次发表在证道学杂志《路西法》(Lucifer）上。利比德描述了各种原子结构在“以太子平面”上不同程度的分解，直至一个基本单元。他将其称为“终极物理原子”—— 一种心形的证道学“生命力”流，据说所有物质都是由这种生命力构成的。利比德和贝桑特将他们的发现与科学家威廉-克鲁克斯（William Crookes）最近提出的所有原子都可能由“原粒子”(protyle）组成的说法联系在一起，“原粒子”是一个世纪前化学家威廉·普鲁特（William Prout）提出的物质基本单位。(普鲁特假定原粒子是氢原子，而克鲁克斯则认为它可能是汤姆森所发现的电子)。

贝森特和利比德的《奥义化学》一书扩展了他们之前的研究，系统地描述了所有元素分解成“难以想象的美丽和辉煌”的最终结构。他们再次绘制了所有已知元

素的一系列越来越复杂的原子结构示意图，并将它们的重量和性质与化学中已知的重量和性质联系起来。但他们也有一些意外收获。他们还报告说发现了一系列与稀有气体密切相关的新元素——“元氖”、“元氩”、“元氪”和“元氙”，以及一对全新的稀有气体——“卡龙”（kalon）和“元卡龙”。

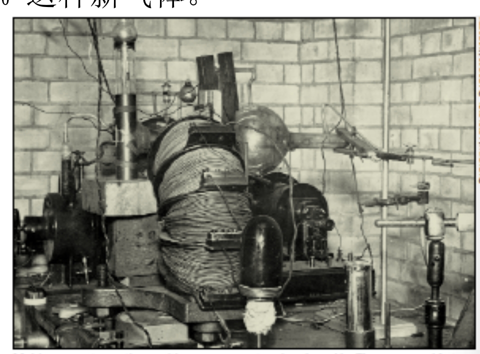


Strange visions – these structural diagrams for neon, meta-neon and other rare gases were obtained through clairvoyance by the British theosophists Annie Besant and Charles Leadbeater. The illustrations appear in their 1907 book *Occult Chemistry*.

奇怪的视像--这些氖、元氖和其他稀有气体的结构图是英国证道学家安妮·贝森特和查尔斯·利比德通过灵视获得的。这些插图出现在他们在 1907 年出版的《奥义化学》一书中。

阿斯顿熟读贝森特和利比德的著作，甚至选择用他们的名字“元氖”来命名他的新气体，这一点很能说明问题。毕竟，命名在科学中是很重要的，它可以反映功劳归属和知识网络。贝森特和利比德的说法甚至可能为阿斯顿和汤姆森提供了一种宝贵的资源，使他们在实验中发现了一种新元素：它给了他们一个“夹子”，让他们可以把氖-22 的反常现象挂在上面并使其合理化。由此看来，证道学很有可能对物理学以及艺术、音乐和哲学等其他领域产生了虽小但重要的影响。

1913 年夏天，阿斯顿认定元氖是“大气中的一种新的基本成分”，他开始着手分离元氖，以便确定其性质。他设计了一个精确到 10^{-9} 克的石英微量天平，用来测量这种微量新型气体的密度，并运用他强大的实验技术试图获得这种气体的样本。他使用的第一种方法——分馏——失败了。第二种方法是反复使用蒸馏管进行扩散提纯，结果较好。从一位法国同事提供的 100 立方厘米的氖开始，经过数千次繁琐的操作，他获得了两个仅为 2-3 立方厘米的高纯度馏分。在 1913 年英国协会会议上，阿斯顿报告说，氖和元氖的原子量分别为 19.9 和 22.1，并得出结论，大气中的氖含有 10-15% 这种新气体。



Making monsters – the positive-ray apparatus developed by Thomson and Aston.

制造怪物——汤姆森和阿斯顿研制的阳极射线装置。

放射性和同位素

当阿斯顿在卡文迪什继续耐心地研究新气体时，两次干预促使他重新解释了元电子的含义和意义。第一次是格拉斯哥大学放射性讲师弗雷德里克·索迪（他曾与欧内斯特·卢瑟福共同发现了放射性的分解理论）。作为一名放射化学家，索迪最近提出了“同位素元素”或″“同位素”理论——不同质量的原子在元素周期表中占据相同的位置，化学上视其为同元素（译者注：指质子数相同）。然而，这一理论受到了猛烈的批评，索迪需要尽可能找到更多支持证据。他抓住阿斯顿的研究成果，声称氖和元氖是轻元素中“同位素”的例子——他希望这样可以扩展并将他的概念嵌入狭隘的放射性领域之外。

就在同一时刻，当时与卢瑟福在曼彻斯特共事的尼尔斯·玻尔（Niels Bohr）提出，可以从他同事的新的、仍在探索中的原子核理论来理解同位素。玻尔还明确将氖和元氖列为轻元素中的“同位素”。他认为，根据卢瑟福的理论，这些物质应该具有相同的核电荷和电子构型，但质量不同，内部核结构也不同。这是一个有力的论据，卢瑟福本人很快也采用了这一论据来推广他的原子核理论。然而，对许多科学家来说，这并不是不证自明的——尤其是因为它的双刃性。正如玻尔所说，同位素是“卢瑟福理论的必然结果，同时也是‘证明’”。选择相信在这里也很重要。

到 1914 年夏天，卢瑟福的原子核理论与索迪的同位素之间开始形成一个新的相互支持的证据体系。阿斯顿的氖和元氖是确定同位素概念适用于所有元素（而不仅仅是放射性元素）的重要因素。第一次世界大战爆发后，科学家们都被动员起来，大大减少了研究工作，但科学讨论仍尽可能地继续进行。借调到范堡罗（Farnborough）皇家飞机制造厂的阿斯顿与弗雷德里克·林德曼（Frederick Lindemann）等人讨论了元氖和同位素假说，林德曼后来（作为切尔韦尔勋爵，即 Lord Cherwell）成为丘吉尔的科学顾问。卢瑟福和玻尔继续推广原子核理论，而索迪则扩大了他对同位素的论证，包括解释非整数原子量等现象。

1917 年，卢瑟福用 α 粒子分解了氮原子核，这一实验有力地证明了核假说的正确性，该实验结果于 1919 年发表，极大地说服了之前对原子结构问题持怀疑或轻视态度的人。此时，卢瑟福刚刚接替汤姆森成为卡文迪什实验室的负责人。阿斯顿回到剑桥后，开始研制一种新形式的阳极射线频谱仪，从另一个角度探讨氖的问题。他将其称为“质量频谱仪”，以区别于汤姆森的仪器。令他大吃一惊的是，这台仪器产生了氯和许多其他元素的“同位素”形式。随着卢瑟福和原子核理论的兴起，阿斯顿现在为自己的工作找到了新的赞助人，也为解释从他的机器中产生的“大量同位素”找到了现成的工具，因为他又一次来遵循元素周期表顺序开展工作。

放射性和阳极射线的证据相辅相成——原子核在精心构建的（而且经常是有争议的）论证中结合在一起——现在看来是自然和不可避免的。索迪和阿斯顿分别获得 1921 年和 1922 年诺贝尔化学奖，确立了同位素核解释的新正统性。只有汤姆森，这位如今已被边缘化的人物，仍在继续怀疑。

历史被改写

奥威尔式的历史改写就是从这里开始的。在他的诺贝尔演讲和 1922 年出版的极具影响力的教科书《同位素》中，阿斯顿重构了自己的工作历史，使氖-22 和同位素之间的联系显得简单明了。“元元素”（meta-elements）的说法被（正确地）归功于克鲁克斯，但却被认为是通往同位素核解释的道路上被人为拉直的一条错误道路。所有与奥义化学有关的内容都被删除了。这段重建的历史很快被接受为传统的说法。1935 年，当他在诺里奇（Norwich）再次向英国协会发表演讲时，阿斯顿的主题——“同位素的故事”——已经成为核物理学史上一个耳熟能详的寓言。但它掩盖了重新诠释元中子以及如何将同位素和原子核结合在一起的复杂的智力工作。

索迪在 1936 年向一位同事抱怨“与我们这个时代的发现史相关的传奇故事层出不穷……人们很容易陷入这样一个误区，即认为在发现之后看起来显而易见的事情，在发现之前也是显而易见的”，他很可能想到了阿斯顿。然而，阿斯顿对科学史的改写是有目的的。它将同位素和原子核理论与一系列他和他的新导师们会感到尴尬的观点割裂开来。这使得原子核理论似乎一直是原子结构的显而易见的合理解释，他也同时抹去了他自己早期工作的线索。或许，这也是某种科学历史观所致吧！

1945 年 11 月，阿斯顿在剑桥去世，三个月后，广岛和长崎遭受了核爆炸，而他所钟爱的同位素正是核爆炸的罪魁祸首。尽管他改写了历史，但人们对原子的证道学解释的兴趣并没有完全消失。20 世纪 80 年代，英国理论物理学家斯蒂芬·菲利普斯（Stephen Phillips）重新树立了贝森特和利比德的《奥义化学》。他在《夸克的超越感官感知》（Extra-sensory Perception of Quarks）一书中指出，贝森特和利比德所建议的原子结构与基本粒子物理学的结果之间存在着显著的相似之处。这本书延续了阿斯顿 90 年前建立的科学与证道学之间的联系，并表明科学文化的边缘现在与阿斯顿时代一样丰富多彩。科学创造力的源泉的确很深，有时甚至很奇怪。但这正是科学的趣味所在。

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Occultism and the atom: the curious story of isotopes

Jeff Hughes

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When Francis Aston discovered a new type of neon in 1913, he initially linked it with an atom that had been predicted by two "occult chemists" through a strange form of clairvoyance. But why was this episode later rewritten in the history books?

Occultism and the atom: the curious story of isotopes

Jeff Hughes

THE ROUTES to scientific discovery are sometimes strange. We are all familiar with the story of Newton and the falling apple, or with Friedrich Kekulé's dream of a snake biting its own tail that led to the discovery of benzene's ring-like structure. But such stories – engaging though they might be – are often mythical. They serve a function in science, emphasizing individual psychology and the flash of inspiration from a heroic scientific genius, over the more routine and collective aspects of scientific work.

Romanticism aside, however, the history of science – like Orwell's Big Brother state – usually writes and rewrites history to remove inconvenient facts, mistakes and idiosyncrasies, leaving only a rationalized path to our present knowledge, or what historians sometimes call "whig" history. In so doing, it not only distorts the actual course of historical events but also gives a misleadingly simplistic picture of the richness of scientific activity and the interactions between science and broader culture.

Clairvoyant connection – Francis Aston trying to separate neon and "meta-neon" in about 1913.

In the history of physics, for example, the discovery of isotopes by Frederick Soddy and Francis Aston is usually cast as part of a linear sequence of discoveries in atomic and nuclear physics. The story, we are told, began with the discovery of radioactivity in the 1890s, continued with the discovery of the nucleus (1911), isotopes (1913), wave mechanics (1920s) and the neutron (1932), before leading to nuclear fission (1938) and, ultimately, the atomic bomb (1945).

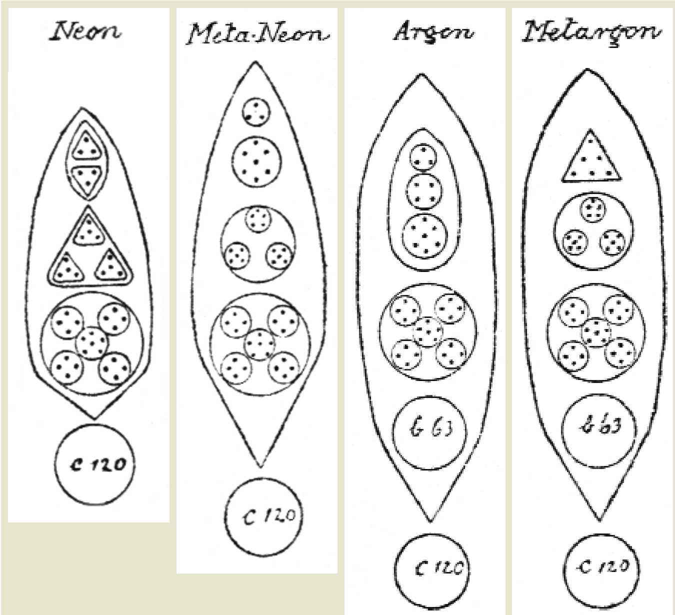
This bomb-directed story naturally emphasizes the key scientific elements of atomic weapons. But in doing so, it over-rationalizes the way in which these discoveries were achieved, and gives a deceptive picture of the process of scientific discovery and of the reasons why science develops as it does. If we look at the actual course of events without the benefit of hindsight, we learn that fact can, indeed, sometimes be stranger than fiction.

J J Thomson and the 'positive rays'

The 1890s were convulsive years for the physical sciences. The discoveries of the rare gases, X-rays, radioactivity and the Zeeman effect – as well as the elaboration of ionic theory and the electrical theory of matter – radically changed our understanding of the physical world. At the Cavendish Laboratory in Cambridge, J J Thomson's 1897 discovery of the "corpuscles" that made up cathode rays – the particles that would later be known as electrons – opened up the microphysics of the atom. But while public audiences marvelled at the spooky new X-ray photography, Thomson and his students, as well as physicists elsewhere, took up the challenge of finding out more about atoms and radiation.

Thomson spent several years trying to work out a scheme of atomic structure based on his corpuscles. He tried various arrangements of corpuscles revolving inside each atom, hoping to find a way of explaining its physical and chemical properties. But although he understood the nature of negative electricity fairly well in terms of rotating rings of corpuscles, he was mystified by the counterbalancing "positive electricity" that must exist in a neutral atom. Thomson thought of it more or less as a massless cement holding the corpuscles – and hence the atom – together. At first, he believed that the number of corpuscles in an atom had to be about the same as the atomic-mass number. Scattering and other experiments soon led him to reduce the number of corpuscles in his model, but this made it radiatively unstable. Thomson concluded that positive electricity must have mass – and that it must, indeed, contain most of the mass of the atom.

In 1906 Thomson therefore began a new research project on "positive rays" – the ions that stream through a hole in the cathode of a gas-discharge tube – in an attempt to understand positive electricity and its role in atomic structure. Working



Strange visions – these structural diagrams for neon, meta-neon and other rare gases were obtained through clairvoyance by the British theosophists Annie Besant and Charles Leadbeater. The illustrations appear in their 1907 book *Occult Chemistry*.

mainly through his assistant Ebenezer Everett and his student George Kaye – who later co-wrote Kaye and Laby's famous *Tables of Physical and Chemical Constants* – Thomson modified the technique that he had used in his successful cathode-ray experiments a decade earlier. By arranging electric and magnetic fields round the discharge tube, he was able to direct the positive rays onto a small fluorescent screen. Theory indicated that the rays should form a series of parabolas on the screen, with each parabola created by rays that have the same charge-to-mass ratio (e/m) but different speeds.

In practice, however, the experiments were deeply troublesome. The results were highly sensitive to changes in pressure, and achieving low pressures was particularly difficult. The maximum value of e/m was always found to be that for the hydrogen ion, H^+, regardless of the gas in the tube. On this basis, Thomson concluded that H^+ was a basic constituent of all atoms. Other than this, however, it was hard to make consistent sense of the experiments, which by 1909 had reached an impasse. To make matters worse, Kaye left the Cavendish for the National Physical Laboratory the following year. Thomson was stuck.

He began to cast around for a new assistant. Fortuitously, he took the advice of his friend John Henry Poynting from Birmingham University and offered the post to one of Poynting's former students – Francis William Aston. A lover of fireworks and mechanical things from an early age, Aston had studied chemistry and physics at Mason College – the forerunner of Birmingham University – in the mid-1890s. He had become extremely skilled in glass-blowing and the use of tools, and set up his own workshop and lab in a loft at home. The sensational discovery of X-rays fascinated him, and he spent much of his spare time outside of his day job in a Wolverhampton brewery designing and building his own gas-discharge apparatus and pumps. In 1903 Poynting offered Aston a scholarship to return to Birmingham University, where he pursued this gas-discharge work in a leisurely fashion for the next few years.

Grotesque monsters

Aston's arrival at the Cavendish in 1910 significantly changed Thomson's experimental approach. An expert in coaxing the best from a piece of apparatus by systematic, incremental tinkering, Aston found ways of achieving and working at much lower pressures than Thomson had ever achieved before. Characteristic atomic and molecular parabolas for different gases now became visible for the first time, and Aston introduced photographic methods to detect and record them. Thomson now began to realize that the positive-ray apparatus could be used to identify gases and their constituents, and by 1912 he and Aston were promoting the "positive-ray spectrograph" as a form of chemical analysis.

While he continued modifying and refining the technique, Aston also embarked on a systematic survey of gases using the new method. Like Thomson, he also saw the rarefied conditions of the gas discharge as a productive source of unusual phenomena for further investigation. "We need not", he wrote, "be surprised at finding upon the [photographic] plates lines corresponding to molecules found neither in the heavens above nor in the earth beneath; nor need those of us who are chemists hold up our head in horror at such unnatural and grotesque monsters of the world of molecules as H_3, CH, CH_2, CH_3, N_3 etc. etc. Rather we should look forward to this line of investigation as an extremely hopeful field in which to study the actual mechanism of dissociation, ionisation and chemical interaction."

This was a significant change in the *meaning* of the positive-ray experiments. They were no longer just a physical way of investigating positive electricity, but also a means of eliciting novel chemical phenomena – and perhaps a way of understanding physics and chemistry in common terms. The new direction of the research bore fruit in 1911 when Thomson noticed a line corresponding to atomic mass 3, which appeared sporadically and which he described as "about as elusive a thing as the sea serpent". Designating it "X_3", he spent much of his time over the next few years chasing this monster.

In 1912 Aston found a monster of his own when he introduced neon into the tube. Rare gases like neon were still relatively novel, difficult to obtain and poorly understood. Although neon's atomic weight had then recently been determined to be 20.2, its properties were still a puzzle. When Aston analysed neon in the positive-ray spectrograph, he saw not only the expected parabola corresponding to an atomic mass of about 20 but also a persistent "shadow" parabola corresponding to an atomic mass of 22.

Aston thought that he had discovered a new element closely associated with neon – perhaps a new rare gas or a new feature of the rare gases. He named this new element "meta-neon". It is here that Aston's links with the occult first surface. In a footnote to the paper announcing his discovery to the annual meeting of the British Association (BA) in 1913 in Birmingham, Aston referred to a 1908 publication by Annie Besant and Charles Leadbeater called *Occult Chemistry: A Series of Clairvoyant Observations on the Chemical Elements*.

"By theosophic methods entirely unintelligible to the mere student of physics," noted Aston, "[the authors] claimed to have determined the atomic weights of all the elements known, and several unknown at the time. Among the latter occurs one to which they ascribe an atomic weight of 22.33 (H = 1) and which they call 'Meta Neon'. As this name seems to suit as well as any other, what little we know of the properties of the new gas, I have used it in this paper."

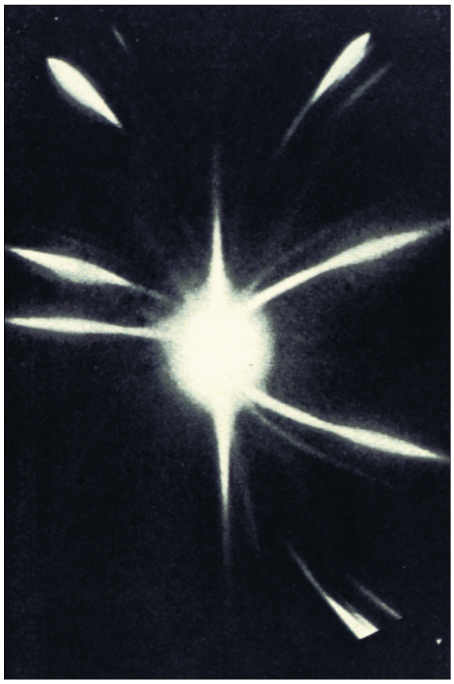
Astral visions

Theosophy – meaning "divine wisdom" – was a centuries-old system of philosophical and religious belief concerning the nature and processes of the divine and their relationship with the phenomenal universe. In its modern form, organized theosophy was a social and intellectual movement founded in the US in the 1870s, and popular in Britain and Europe from the 1880s. One of a number of systems of belief that came to prominence in this period as alternatives to organized religion and scientific rationalism, theosophy drew on ideas from Eastern philosophy, mysticism and ancient occult traditions dating back to Pythagoras. Its blend of esoteric wisdom and spiritual philosophy (including a belief in reincarnation) appealed to Victorian audiences disenchanted by the materialism of much modern science and by a Christianity that they saw as having become compromised by science. In particular, theosophy's emphasis on esoteric wisdom gave it a strong appeal to intellectuals. They saw in it a way of exploring and expressing hidden realities in an increasingly materialistic world without moral or spiritual values.

It is well known, of course, that several notable British physicists of this period – including Lord Rayleigh, Oliver Lodge and Thomson himself – were members of the Society for Psychical Research and were interested in what we might now call paranormal phenomena. Although their positions varied from complete belief to cautious scepticism, they all hoped that physics might be able to shed light on phenomena outside the range of normal experience. Like psychical research and spiritualism, theosophy was intellectually both controversial and fashionable in the early years of the 20th century.

Besant and Leadbeater, to whom Aston referred at the 1913 BA meeting, were two of the leading British theosophists. They had made significant contributions to its philosophy and to the public visibility of the theosophical movement. Their 1905 book *Thought Forms* – a vividly illustrated study of the "astral" auras associated with different moods and emotions – was widely read and had a profound effect on a number of artists and musicians, including Mondrian, Kandinsky and Schoenberg. Besant and Leadbeater saw theosophy as a higher form of science – a means by which natural phenomena and insights unavailable to (or ignored by) the physical sciences could be revealed and tested, and through which deeper universal truths might be attained. In this sense, they saw theosophy and science as complementary.

In the summer of 1895 Leadbeater had first used a form of clairvoyance that he called "astral vision" to "see" inside the atoms of hydrogen, nitrogen and oxygen. His descriptions of the inner architecture of atoms of the various elements were transcribed and first published in the theosophical magazine *Lucifer* in November 1895 under the title "Occult chemistry". Leadbeater described various atomic structures in different degrees of reduction across "etheric sub-planes" down to a fundamental unit. He referred to this as the "ultimate physical atom" – a heart-shaped flow of the theosophical "life force" from which all matter was supposed to be composed. Leadbeater and Besant linked their discoveries to the recent claims of the scientist William Crookes that all atoms might consist of the "protyle" – the elementary unit of matter that had been suggested by the chemist William Prout a century earlier. (Prout had assumed that the protyle was the hydrogen atom, although Crookes suggested that it might be Thomson's electron.)

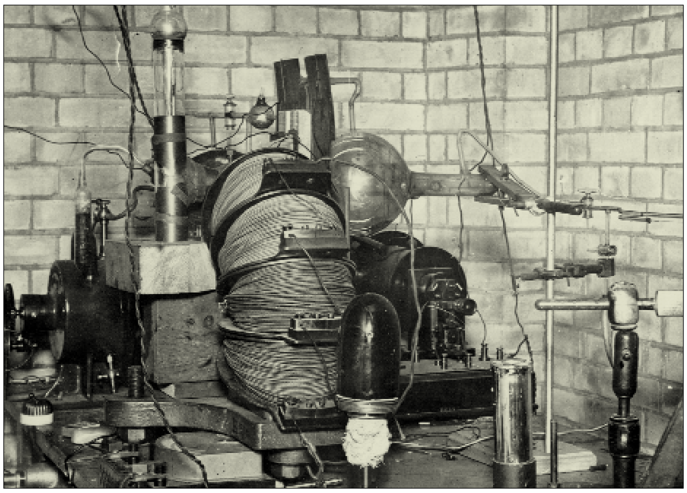


Ghostly shadow? – Aston's positive-ray spectrograph of neon and meta-neon (top right).

Besant and Leadbeater's book *Occult Chemistry* expanded on their earlier research by systematically describing the decomposition of all the elements into their "inconceivably beautiful and brilliant" ultimate structures. Again they produced a series of increasingly complex diagrams of atomic structures of all the known elements, correlating their weights and properties to those known from chemistry. But they also had a few surprises. They reported seeing elements that were "not yet discovered" by conventional science, including one that they called "Occultum", which they claimed had an atomic mass of 3. The pair also reported finding a new series of elements closely associated with the rare gases – "meta-neon", "metargon", "meta-krypton" and "meta-xenon" – as well as an entirely new pair of rare gases, dubbed "kalon" and "meta-kalon".

It is telling that Aston was familiar with Besant and Leadbeater's book, and even more so that he chose to adopt their name "meta-neon" for his new gas. After all, naming is important in science, in reflecting credit attribution and intellectual networks. It may even be that Besant and Leadbeater's claims provided Aston and Thomson with a valuable resource in grounding the experimental discovery of a new element: it gave them a peg, as it were, on which to hang and make sense of the neon-22 anomaly. It thus seems highly likely that theosophy had a small, but significant, impact in physics, as well as in other areas such as art, music and philosophy.

Having decided in the summer of 1913 that meta-neon was "a new elementary constituent of the atmosphere", Aston set about separating and isolating it so that he could determine its properties. He designed a quartz micro-balance that was accurate to 10^{-9} g to measure the density of tiny quantities of the novel gas, and deployed his formidable experimental technique to try to obtain a sample of it. The first method he used – fractional distillation – was a failure. The second, which involved repeated diffusion through pipeclay, produced better results. Starting from 100 cm^3 of neon provided by a French colleague, he obtained – after thousands of tedious operations – two extreme weight fractions of only 2–3 cm^3. At the 1913 BA meeting Aston reported that neon and meta-neon had atomic weights of 19.9 and 22.1, respectively, and concluded that atmospheric neon contained 10–15% of the new gas.



Cavendish Laboratory, Cambridge University

Making monsters – the positive-ray apparatus developed by Thomson and Aston.

Radioactivity and isotopes

As Aston continued his patient work on the new gas at the Cavendish, two interventions led to a reinterpretation of the meaning and significance of meta-neon. The first came from Frederick Soddy, a lecturer in radioactivity at Glasgow University (who had previously co-discovered with Ernest Rutherford the disintegration theory of radioactivity). As a radio-chemist, Soddy had recently developed the theory of "isotopic elements" or "isotopes" – atoms of different masses that occupy the same place in the periodic table and are chemically inseparable. The theory was heavily criticized, however, and Soddy needed all the supporting evidence he could find. He seized on Aston's results and claimed that neon and meta-neon were examples of "isotopes" among the lighter elements – so extending and, he hoped, embedding his concept outside the narrow field of radioactivity.

At the same moment, Niels Bohr, who was then working with Rutherford at Manchester, suggested that isotopes could be understood in terms of his colleague's new and still-speculative nuclear theory of the atom. Bohr also explicitly included neon and meta-neon as examples of "isotopes" among the light elements. He argued that, according to Rutherford's theory, such species should have identical nuclear charge and electronic configurations but different masses and different internal nuclear structures. This was a powerful line of argument, and Rutherford himself soon adopted it to promote his nuclear theory. Yet it was far from self-evident to many scientists – not least because of its double-edged nature. As Bohr put it, isotopes were paradoxically a "necessary consequence and simultaneously 'proof' of Rutherford's theory". Belief was important here, too.

By the summer of 1914 a new matrix of mutually supporting evidence was beginning to coalesce linking Rutherford's nuclear theory and Soddy's isotopes. Aston's neon and meta-neon were important elements in establishing the generality of the isotope concept to all elements, not just the radioactive ones. Although the outbreak of the First World War drastically curtailed research as scientists were mobilized, scientific discussions continued whenever possible. Aston, who was seconded to the Royal Aircraft Establishment at Farnborough, discussed meta-neon and the isotope hypothesis with, among others, Frederick Lindemann, who later (as Lord Cherwell) became Churchill's scientific advisor. Rutherford and Bohr continued to promote the nuclear theory, while Soddy widened his argument for isotopes to include the explanation of phenomena such as non-integral atomic weights.

Rutherford's disintegration of nitrogen nuclei using alpha particles in 1917 was a powerful experimental statement in favour of the nuclear hypothesis, and its publication in 1919 did much to persuade those who had previously doubted or been indifferent to the question of atomic structure. By this time, Rutherford had just succeeded Thomson as head of the Cavendish. When Aston returned to Cambridge, he began developing a new form of the positive-ray spectrograph to explore the neon question from a different angle. He called it a "mass spectrograph" to distinguish it from Thomson's apparatus. To his huge surprise, the device produced "isotopic" forms for chlorine and many other elements. With Rutherford and the nuclear theory in the ascendant, Aston now found a new patron for his work, and a ready vehicle for the interpretation of the "isotopes galore" that tumbled out of his machine as he again worked his way through the periodic table.

The mutually reinforcing evidence from radioactivity and from positive rays – united by the nuclear atom in a carefully constructed (and often contested) argument – now seemed natural and inevitable. The award of the 1921 and 1922

Occult science: the inside story

Historians, like scientists, sometimes make serendipitous discoveries that open up new areas of study, *writes Jeff Hughes*. The story of Aston, the meta-elements and theosophy came to light when I was going through a large grey box of Aston's papers in Cambridge University Library as part of my research on the history of nuclear physics between the wars (*Physics World* July 2000 pp43–48). The papers were uncatalogued, and consisted mainly of offprints of Aston's many published papers, together with some interesting letters from scientific colleagues and a couple of his lab notebooks. Buried among this material was a yellowed, 15-page typed manuscript entitled "On the homogeneity of atmospheric neon".

The document, scarred with what looked like burn marks from pipe ash on the first couple of pages, was undated, and did not correspond to any of Aston's published papers. But from its description of his work on the positive-ray analysis of neon and meta-neon, and from the internal evidence of the other papers he cited, it quickly became clear that it had been written in the second half of 1913. It seemed likely to be a version of the paper that Aston delivered at the British Association's meeting in Birmingham in September 1913, where I knew he had spoken on his neon discovery.

As well as revealing significant new details of Aston's attempts to separate the two forms of neon, the document showed that he had been in touch with Bohr, who had told him about the new nuclear theory of the atom and its implications for the interpretation of neon and meta-neon. But the last page of the paper – after the usual acknowledgments and so on – contained a curious "Note on the name 'Meta Neon'", in which Aston admitted his source for the name.

Initially amazed that he would even be familiar with Besant and Leadbeater's *Occult Chemistry*, I became interested and decided to follow up the theosophical connection. The story that began to emerge about the culture in which Aston worked and the way he produced his results was very different to the one in the historical books and articles I had read. It was obvious that the history had been rewritten from a later perspective. Rising to this challenge, I decided to write a book on the *real* history of Aston, isotopes and the mass-spectrograph. This article is just one small part of that story.

Nobel Prizes for Chemistry to Soddy and Aston, respectively, confirmed the new orthodoxy of the nuclear interpretation of isotopes. Only Thomson, now a marginal figure, continued to doubt.

History rewritten

It is here that the Orwellian rewriting of history begins. In his Nobel lecture and in his influential 1922 textbook *Isotopes*, Aston reconstructed the history of his own work to make the link between neon-22 and isotopes seem straightforward. The language of "meta-elements" was (correctly) attributed to Crookes, but dismissed as a false path on the now artificially straightened road to the nuclear interpretation of isotopes. All reference to occult chemistry was eliminated. This reconstructed history quickly became accepted as the conventional account. By the time he addressed the BA again in 1935 in Norwich, Aston's subject – "The story of isotopes" – had become a familiar parable in the history of nuclear physics. But it covered up the complexity of the intellectual work that had gone into the reinterpretation of meta-neon and how isotopes and the nuclear atom had been brought together.

Soddy might well have been thinking of Aston when he complained to a colleague in 1936 about "the sort of legend that grows up in connection with the history of discoveries in our own time…So easy is it to fall into the error of thinking that things which look obvious after a discovery were just as obvious before". Yet Aston's rewriting of scientific history served a purpose. It disconnected isotopes and the nuclear theory from a set of ideas that he and his new mentors would have found embarrassing. It made the nuclear theory seem always to have been the obvious and plausible account of atomic structure, and effaced one of the sources of his own earlier work. And perhaps, too, it was typical of a certain scientific approach to history!

Aston died in Cambridge in November 1945, three months after the nuclear bombings of Hiroshima and Nagasaki that his beloved isotopes helped bring about. Despite his rewriting of history, interest in the theosophical interpretation of the atom has not died out entirely. In the 1980s the British theoretical physicist Stephen Phillips resurrected Besant and Leadbeater's *Occult Chemistry*. His book *Extra-sensory Perception of Quarks* points to remarkable similarities between Besant and Leadbeater's atomic structures and results from elementary particle physics. It sustains the connections between science and theosophy made by Aston 90 years ago, and shows that the margins of scientific culture are as rich and varied now as they were in Aston's day. The wellsprings of creativity in science do indeed run deep, and sometimes strange. But that is what makes science interesting.

Further reading

I Falconer 1988 J J Thomson's work on positive rays, 1906–1914 *Historical Studies in the Physical Sciences* **18** 265–310

J Oppenheim 1985 *The Other World. Spiritualism and Psychic Research in England, 1850–1914* (Cambridge University Press)

S M Phillips 1980 *Extra-Sensory Perception of Quarks* (The Theosophical Publishing House, Madras and London)

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