

## (12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization

International Bureau



(10) International Publication Number

WO 2018/146469 A1

(43) International Publication Date

16 August 2018 (16.08.2018)

## (51) International Patent Classification:

*C07D 403/12* (2006.01) *A61K 31/427* (2006.01)  
*C07D 401/12* (2006.01) *A61K 31/44* (2006.01)  
*C07D 417/12* (2006.01) *A61P 35/00* (2006.01)

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

## (Published:

— with international search report (Art. 21(3))

## (21) International Application Number:

PCT/GB2018/050343

## (22) International Filing Date:

07 February 2018 (07.02.2018)

## (25) Filing Language:

English

## (26) Publication Language:

English

## (30) Priority Data:

62/455,639 07 February 2017 (07.02.2017) US  
 62/594,799 05 December 2017 (05.12.2017) US

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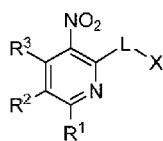
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(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) **Title:** HETEROARYLSULFONYL-SUBSTITUTED PYRIDINES AND THEIR USE IN THE TREATMENT OF CANCER



(1)

(57) **Abstract:** There is provided compounds of formula I (I) or pharmaceutically-acceptable salts thereof, wherein L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> and X have meanings provided in the description, which compounds are useful in the treatment of cancers.

## HETEROARYLSULFONYL-SUBSTITUTED PYRIDINES AND THEIR USE IN THE TREATMENT OF CANCER

### Field of the Invention

5

The present invention relates to novel compounds and compositions, and their use in the treatment of cancer. In particular, the invention relates to novel compounds, compositions and methods for the treatment of cancers through specific and potent inhibition of thioredoxin reductase with minimal inhibition of glutathione reductase.

10

### Background of the Invention

The listing or discussion of an apparently prior-published document in this specification should not necessarily be taken as an acknowledgement that the document is part of the 15 state of the art or is common general knowledge.

Although the increased understanding of the role of oncogenes, and the development of new anticancer treatments and diagnosis, have improved the life expectancy of cancer patients, there is still a high medical need to find more effective and less toxic treatments 20 for cancers, such as breast cancer, head and neck cancer, glioblastoma, melanoma, leukaemia, and colon and lung cancer.

It is well known that excessive production of reactive oxygen species is a common feature of cancer cells due to their distorted metabolism and exaggerated replicative drive. Cancer 25 cells are able to survive their unnaturally high production of reactive oxygen species through concomitant upregulation of robust antioxidant defence mechanisms.

Radiotherapy and chemotherapy protocols compete against antioxidant defence mechanisms, further increasing reactive oxygen species levels beyond adapted thresholds 30 through targeting of multiple cellular compartments and targets. Thus, sensitization of cancer cells to their endogenous reactive oxygen species production can additionally induce cancer cell death. In contrast, normal cells have reserved capacity to combat oxidative stress. With this in mind, it has been suggested that if reactive oxygen species levels could be further increased, or the cellular defences against reactive oxygen species 35 could be deliberately impaired, these systems may serve to allow for a possible therapeutic mechanism of action for anticancer therapy (Luo, J., *et al.*, *Cell*, **136**, 823 (2009); Trachootham, D., *et al.*, *Nat Rev Drug Discov*, **8**, 579 (2009)).

Increased tolerance to oxidative stress of cancer cells can occur through activation of the two major antioxidant systems in human and other mammals: the glutathione and thioredoxin systems. Concomitant inhibition of the glutathione and thioredoxin systems 5 therefore has been proposed as a mechanism for anticancer activity (Harris, I.S., *et al.*, *Cancer Cell* **27**, 211 (2015); Mandal, P.K., *et al.*, *Cancer Res*, **70**, 9505-9514 (2010); Fath, M.A., *et al.*, *Clin Cancer Res.*, **17**, 6206 (2011)).

10 Cytosolic thioredoxin reductase is a key enzyme for the whole cytosolic thioredoxin system, which in turn is responsible for a cascade of signalling events and antioxidant activities (Arnér, E. S. J., *Biochim Biophys Acta*, **1790**, 495-526 (2009)). A high expression level of cytosolic thioredoxin reductase in various cancers correlates to a more severe cancer phenotype, chemotherapeutic drug resistance, and poor prognosis.

15 However, as normal, non-cancerous cells require either the glutathione or the thioredoxin systems for survival (Arnér, E.S. & Holmgren, A., *Eur J Biochem*, **267**, 6102 (2000); Lillig, C.H., Berndt, C. & Holmgren, A., *Biochim Biophys Acta*, **1780**, 1304 (2008); Prigge, J.R., *et al.*, *Free Radic Biol Med*, **52**, 803 (2012)), it is difficult to therapeutically target both of these antioxidant systems without triggering major unwanted toxicities.

20 It has been suggested that several chemotherapeutic protocols for anticancer treatment involve inhibition of cytosolic thioredoxin reductase together with other components of the cell (Becker, K. *et al.* *Eur. J. Biochem.*, **267**, 6118 (2000)). For example, motexafin gadolinium, marketed as a radiosensitizing drug and thioredoxin reductase inhibitor, is also 25 a potent ribonucleotide reductase inhibitor (Hashemy, S. I., *et al.*, *J Biol Chem*, **281**, 10691 (2006)). Auranofin, a potent thioredoxin reductase inhibitor, concomitantly localizes to and damages the mitochondria (Cox, A.G., *et al.*, M.B., *Biochem Pharmacol*, **76**, 1097-1109 (2008); Krishnamurthy, D., *et al.*, *J Med Chem*, **51**, 4790 (2008); Rigobello, M.P., *et al.*, *Free Radic Res*, **39**, 687 (2005)).

30 The structure and function of thioredoxin reductase, biological effects associated with its inhibition, such as in its potential as a mechanism for cancer treatment, and compounds previously disclosed as potential inhibitors are reviewed in Zhang, B. *et al.*, *Expert Opinion on Therapeutic Patents* (2016).

35 The present innovation relates to the development and usage of novel compounds specifically and potently targeting cytosolic thioredoxin reductase, without targeting the

closely related flavoprotein glutathione reductase that supports the function of the glutathione system, as a means of obtaining a new efficient anticancer treatment that at the same time presents limited toxic side effects.

5 In particular, the inventors have unexpectedly found that novel, pyridinyl sulfone compounds may achieve highly selective inhibition of cytosolic thioredoxin reductase by acting as strongly-binding (and, in some cases, effectively irreversible) inhibitors of the enzyme without causing significant inhibition of glutathione reductase.

10 Specifically, by potently inhibiting thioredoxin reductase selectively over glutathione reductase, the novel pyridinyl sulfones have the potential to be effective against cancer forms having dysfunctional redox status, with minimal general toxic effects to normal cells. Such inhibitors may also be a suitable adjuvant therapy to be used in conjunction with radiotherapies or other chemotherapeutic approaches. Based on these surprising results,

15 the present invention aims to provide new treatments for cancers.

Certain heteroarylsulfonyl-nitropyridines have been synthesized or alleged to be commercially available but with no use ascribed to them, as described in: Takahashi, T., *et al*, Chem Pharm Bull, **6**, 369 (1958) and Talik, Z., *et al*, Prace Naukowe Akademii 20 Ekonomicznej imienia Oskara Langego we Wroclawiu **255**, 137 (1984).

International patent application WO 2010/138820 refers to the preparation of various *N,N'*-diarylureas and *N,N'*-diarylthioureas that are suggested to act to inhibit translation initiation and which are stated to be useful in the treatment of, for example, proliferative disorders.

25 This publication also lists a number of compounds identified in a chemical library.

International patent application WO 03/051366 describes certain pyridines as kinase inhibitors and their use in treating cancer. However, none of the exemplified pyridines carry nitro substituents and none are linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent application WO 2005/007621 describes certain compounds as ubiquitin ligase inhibitors and their use in treating cell proliferative diseases. However, none of exemplified compounds contain a nitro substituted pyridine that is linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent application WO 99/36391 describes two benzenesulfonamides as

therapeutic agents. Neither contains a pyridine ring having a nitro substituent.

International patent application WO 2005/121121 describes certain compounds as glucose metabolism modulators useful for the treatment of, for example, diabetes and 5 obesity. However, none of the exemplified compounds contain a nitro substituted pyridine linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent application WO 2007/124546 describes 3-cyano-4,6-diarylsubstituted 10 pyridines useful for the treatment of viral infections. However, none of the exemplified compounds contain a nitro substituted pyridine linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent application WO 95/29897 describes certain (H<sup>+</sup>/K<sup>+</sup>)ATPase inhibitors 15 and their use in treating viral infections. However, none of the exemplified compounds contain a nitro substituted pyridine linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent application WO 98/54139 describes a process for the preparation of 20 pyridines linked to, for example, an unsubstituted phenyl *via* a sulfonyl group. However, none of the exemplified compounds contain a nitro substituted pyridine linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent applications WO 2013/119931, WO 99/010320, WO 99/18096 and WO 25 99/017777 describe certain compounds and their use in treating conditions such as cancer. However, none of the exemplified compounds contain a nitro substituted pyridine linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent application WO 01/064642 describes certain compounds and their use 30 in treating coagulation disorders. However, none of the exemplified compounds contain a nitro substituted pyridine linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

International patent application WO 2011/022440 describes certain compounds and their use 35 for treating proliferative disorders. However, none of the exemplified compounds contain a nitro substituted pyridine linked *via* a sulfonyl moiety to an optionally substituted heteroaryl group.

Chinese patent application CN 102206172 describes certain antiviral compounds. However, none of the exemplified compounds contain a nitro substituted pyridine linked via a sulfonyl moiety to an optionally substituted heteroaryl group.

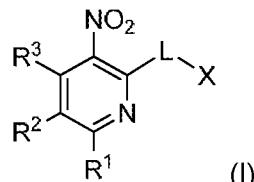
## 5 Detailed Description of the Invention

It has now been found that certain nitro substituted pyridines linked via a sulfonyl moiety to an optionally substituted heteroaryl group have surprising properties which render such compounds useful in the treatment of cancers.

10

### Compounds of the invention

In a first aspect of the invention, there is provided a compound of formula I



15

(I)

or a pharmaceutically acceptable salt thereof, wherein:

L represents  $-S(O)_n-$ ;

20

n represents 2 or 1;

X represents a heteroaryl group, attached to L via a carbon atom, optionally substituted by one or more groups independently selected from Y;

25

$R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo,  $R^{a1}$ ,  $-CN$ ,  $-A^{a1}-C(Q^{a1})R^{b1}$ ,  $-A^{b1}-C(Q^{b1})N(R^{c1})R^{d1}$ ,  $-A^{c1}-C(Q^{c1})OR^{e1}$ ,  $-A^{d1}-S(O)_pR^{f1}$ ,  $-A^{e1}-S(O)_pN(R^{g1})R^{h1}$ ,  $-A^{f1}-S(O)_pOR^{i1}$ ,  $-N_3$ ,  $-N(R^{j1})R^{k1}$ ,  $-N(H)CN$ ,  $-NO_2$ ,  $-ONO_2$ ,  $-OR^{l1}$  or  $-SR^{m1}$ ;

30

each  $A^{a1}$  to  $A^{f1}$  independently represents a single bond,  $-N(R^{p1})-$  or  $-O-$ ;

each  $Q^{a1}$  to  $Q^{c1}$  independently represents  $=O$ ,  $=S$ ,  $=NR^{n1}$  or  $=N(OR^{o1})$ ;

each  $R^{a1}$  and  $R^{f1}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{1a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{1b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{1c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{1d}$ ;

each  $R^{b1}$ ,  $R^{c1}$ ,  $R^{d1}$ ,  $R^{e1}$ ,  $R^{g1}$ ,  $R^{h1}$ ,  $R^{i1}$ ,  $R^{j1}$ ,  $R^{k1}$ ,  $R^{l1}$ ,  $R^{m1}$ ,  $R^{n1}$ ,  $R^{o1}$  and  $R^{p1}$  independently represents H,  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{1a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{1b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{1c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{1d}$ ;

any of  $R^{c1}$  and  $R^{d1}$ ,  $R^{g1}$  and  $R^{h1}$  and/or  $R^{j1}$  and  $R^{k1}$  are linked together to form, together with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from halo, and  $C_{1-3}$  alkyl,  $C_{2-3}$  alkenyl or  $C_{2-3}$  alkynyl each optionally substituted by one or more halo, and  $=O$ ;

each  $G^{1a}$  and  $G^{1b}$  independently represents halo,  $-CN$ ,  $-N(R^{a2})R^{b2}$ ,  $-OR^{c2}$ ,  $-SR^{d2}$  or  $=O$ ;

each  $G^{1c}$  and  $G^{1d}$  independently represents halo,  $-CN$ ,  $-N(R^{a2})R^{b2}$ ,  $-OR^{c2}$  or  $-SR^{d2}$ ;

each  $R^{a2}$ ,  $R^{b2}$ ,  $R^{c2}$  and  $R^{d2}$  independently represents H or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more fluoro; or

$R^{a2}$  and  $R^{b2}$  are linked together to form, along with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from fluoro,  $C_{1-3}$  alkyl,  $C_{2-3}$  alkenyl or  $C_{2-3}$  alkynyl each optionally substituted by one or more fluoro;

each  $Y$  independently represents halo,  $R^{a3}$ ,  $-CN$ ,  $-A^{a2}-C(Q^{a2})R^{b3}$ ,  $-A^{b2}-C(Q^{b2})N(R^{c3})R^{d3}$ ,  $-A^{c2}-C(Q^{c2})OR^{e3}$ ,  $-A^{d2}-S(O)_qR^{f3}$ ,  $-A^{e2}-S(O)_qN(R^{g3})R^{h3}$ ,  $-A^{f2}-S(O)_qOR^{i3}$ ,  $-N_3$ ,  $-N(R^{j3})R^{k3}$ ,  $-N(H)CN$ ,  $-NO_2$ ,  $-ONO_2$ ,  $-OR^{l3}$  or  $-SR^{m3}$ ;

each  $Q^{a2}$  to  $Q^{c2}$  independently represents  $=O$ ,  $=S$ ,  $=NR^{n3}$  or  $=N(OR^{o3})$ ;

each  $A^{a2}$  to  $A^{f2}$  independently represents a single bond,  $-N(R^{p3})-$  or  $-O-$ ;

each  $R^{a3}$  and  $R^{f3}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each

5 optionally substituted by one or more groups independently selected from  $G^{2a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{2b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{2c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{2d}$ ;

10 each  $R^{b3}$ ,  $R^{c3}$ ,  $R^{d3}$ ,  $R^{e3}$ ,  $R^{g3}$ ,  $R^{h3}$ ,  $R^{i3}$ ,  $R^{j3}$ ,  $R^{k3}$ ,  $R^{l3}$ ,  $R^{m3}$ ,  $R^{n3}$ ,  $R^{o3}$  and  $R^{p3}$  independently represents H,  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{2a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{2b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{2c}$ , or heteroaryl optionally substituted by one or 15 more groups independently selected from  $G^{2d}$ ; or

any two  $R^{c3}$  and  $R^{d3}$ ,  $R^{g3}$  and  $R^{h3}$  and/or  $R^{i3}$  and  $R^{k3}$  are linked together to form, along with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one 20 or more groups independently selected from heterocyclyl optionally substituted by one or more groups independently selected from  $G^{2b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{2c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{2d}$ , and  $=O$ ;

25 each  $G^{2a}$  independently represents halo,  $-CN$ ,  $-N(R^{j4})R^{k4}$ ,  $-OR^{l4}$ ,  $-SR^{m4}$  or  $=O$ ;

each  $G^{2b}$  independently represents halo,  $R^{a4}$ ,  $-CN$ ,  $-N(R^{j4})R^{k4}$ ,  $-OR^{l4}$ ,  $-SR^{m4}$  or  $=O$ ;

each  $G^{2c}$  and  $G^{2d}$  independently represents halo,  $R^{a4}$ ,  $-CN$ ,  $-A^{a3}-C(Q^{a4})R^{b4}$ ,

30  $-A^{b3}-C(Q^{b3})N(R^{c4})R^{d4}$ ,  $-A^{c3}-C(Q^{c3})OR^{e4}$ ,  $-A^{d3}-S(O)_qR^{f4}$ ,  $-A^{e3}-S(O)_qN(R^{g4})R^{h4}$ ,  $-A^{f3}-S(O)_qOR^{i4}$ ,  $-N_3$ ,  $-N(R^{j4})R^{k4}$ ,  $-N(H)CN$ ,  $-NO_2$ ,  $-ONO_2$ ,  $-OR^{l4}$  or  $-SR^{m4}$ ;

each  $Q^{a3}$  to  $Q^{c3}$  independently represents  $=O$ ,  $=S$ ,  $=NR^{n4}$  or  $=N(OR^{o4})$ ;

35 each  $A^{a3}$  to  $A^{f3}$  independently represents a single bond,  $-N(R^{p4})-$  or  $-O-$ ;

each  $R^{a4}$  and  $R^{i4}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{3a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{3b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{3c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{3d}$ ;

each  $R^{b4}$ ,  $R^{c4}$ ,  $R^{d4}$ ,  $R^{e4}$ ,  $R^{g4}$ ,  $R^{h4}$ ,  $R^{i4}$ ,  $R^{j4}$ ,  $R^{k4}$ ,  $R^{l4}$ ,  $R^{m4}$ ,  $R^{n4}$ ,  $R^{o4}$  and  $R^{p4}$  independently represents H,  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{3a}$  or heterocyclyl optionally substituted by one or more groups independently selected from  $G^{3b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{3c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{3d}$ ; or

any of  $R^{c4}$  and  $R^{d4}$ ,  $R^{g4}$  and  $R^{h4}$  and/or  $R^{j4}$  and  $R^{k4}$  are linked together to form, together with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected  $G^{3b}$ ;

each  $G^{3a}$  and  $G^{3b}$  independently represents halo,  $R^{a5}$ , -CN, - $N(R^{b5})R^{c5}$ , - $OR^{d5}$ , - $SR^{e5}$  or =O;

each  $R^{a5}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^4$ ;

each  $R^{b5}$ ,  $R^{c5}$ ,  $R^{d5}$  and  $R^{e5}$  independently represents H, or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^4$ ;

each  $R^{b5}$  and  $R^{c5}$  are linked together to form, together with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from  $G^4$ ;

each  $G^4$  independently represents halo,  $R^{a6}$ , -CN, - $N(R^{b6})R^{c6}$ , - $OR^{d6}$  or =O;

each  $R^{a6}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more fluoro;

each  $R^{b6}$ ,  $R^{c6}$  and  $R^{d6}$  independently represents H, or C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl each optionally substituted by one or more fluoro; and

each p and q independently represents 1 or 2,

5

which compounds and pharmaceutically acceptable salts thereof may be referred to as compounds of the invention,

but with the provisos that the compound of formula I does not represent:

10

(A)

3-nitro-2-(pyridin-2-ylsulfonyl)pyridine,  
2-((3-nitropyridin-2-yl)sulfonyl)pyrimidine, or  
*N*-(6-chloro-2-((5-chloro-3-nitropyridin-2-yl)sulfonyl)pyridin-3-yl)acetamide;

15

or

(B)

3-nitro-2-[(3-nitro-2-thienyl)sulfinyl]-pyridine.

20

For the avoidance of doubt, compounds of formula I and pharmaceutically acceptable salts thereof, not including the provisos, may be referred to herein as compounds of the invention. Similarly, references to compounds of the first aspect of the invention will refer to compounds of formula I as defined in the first aspect of the invention, including the provisos, and pharmaceutically acceptable salts thereof. As such, compounds of the first aspect of the invention represent a particular embodiment of compounds of the invention.

The skilled person will understand that references herein to compounds of the invention (e.g. compounds of the first aspect of the invention) will include references to all embodiments and particular forms thereof.

Unless indicated otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention pertains.

30

Pharmaceutically-acceptable salts include acid addition salts and base addition salts. Such salts may be formed by conventional means, for example by reaction of a free acid

or a free base form of a compound of the invention with one or more equivalents of an appropriate acid or base, optionally in a solvent, or in a medium in which the salt is insoluble, followed by removal of said solvent, or said medium, using standard techniques (e.g. *in vacuo*, by freeze-drying or by filtration). Salts may also be prepared by exchanging 5 a counter-ion of a compound of the invention in the form of a salt with another counter-ion, for example using a suitable ion exchange resin.

Particular acid addition salts that may be mentioned include carboxylate salts (e.g. formate, acetate, trifluoroacetate, propionate, isobutyrate, heptanoate, decanoate, 10 caprate, caprylate, stearate, acrylate, caproate, propiolate, ascorbate, citrate, glucuronate, glutamate, glycolate,  $\alpha$ -hydroxybutyrate, lactate, tartrate, phenylacetate, mandelate, phenylpropionate, phenylbutyrate, benzoate, chlorobenzoate, methylbenzoate, hydroxybenzoate, methoxybenzoate, dinitrobenzoate, *o*-acetoxybenzoate, salicylate, 15 nicotinate, isonicotinate, cinnamate, oxalate, malonate, succinate, suberate, sebacate, fumarate, malate, maleate, hydroxymaleate, hippurate, phthalate or terephthalate salts), halide salts (e.g. chloride, bromide or iodide salts), sulfonate salts (e.g. benzenesulfonate, 20 methyl-, bromo- or chloro-benzenesulfonate, xylenesulfonate, methanesulfonate, ethanesulfonate, propanesulfonate, hydroxyethanesulfonate, 1- or 2- naphthalene-sulfonate or 1,5-naphthalenedisulfonate salts) or sulfate, pyrosulfate, bisulfate, sulfite, bisulfite, phosphate, monohydrogenphosphate, dihydrogenphosphate, metaphosphate, pyrophosphate or nitrate salts, and the like.

Particular base addition salts that may be mentioned include salts formed with alkali metals (such as Na and K salts), alkaline earth metals (such as Mg and Ca salts), organic bases 25 (such as ethanolamine, diethanolamine, triethanolamine, tromethamine and lysine) and inorganic bases (such as ammonia and aluminium hydroxide). More particularly, base addition salts that may be mentioned include Mg, Ca and, most particularly, K and Na salts.

30 For the avoidance of doubt, compounds of the invention may exist as solids, and thus the scope of the invention includes all amorphous, crystalline and part crystalline forms thereof, and may also exist as oils. Where compounds of the invention exist in crystalline and part crystalline forms, such forms may include solvates, which are included in the scope of the invention. Compounds of the invention may also exist in solution.

Compounds of the invention may contain double bonds and may thus exist as *E* (*entgegen*) and *Z* (*zusammen*) geometric isomers about each individual double bond. All such isomers and mixtures thereof are included within the scope of the invention.

5 Compounds of the invention may also exhibit tautomerism. All tautomeric forms and mixtures thereof are included within the scope of the invention.

Compounds of the invention may also contain one or more asymmetric carbon atoms and may therefore exhibit optical and/or diastereoisomerism. Diastereoisomers may be 10 separated using conventional techniques, e.g. chromatography or fractional crystallisation. The various stereoisomers may be isolated by separation of a racemic or other mixture of the compounds using conventional, e.g. fractional crystallisation or HPLC, techniques. Alternatively the desired optical isomers may be made by reaction of the appropriate 15 optically active starting materials under conditions which will not cause racemisation or epimerisation (i.e. a 'chiral pool' method), by reaction of the appropriate starting material with a 'chiral auxiliary' which can subsequently be removed at a suitable stage, by derivatisation (i.e. a resolution, including a dynamic resolution); for example, with a homochiral acid followed by separation of the diastereomeric derivatives by conventional means such as chromatography, or by reaction with an appropriate chiral reagent or chiral 20 catalyst all under conditions known to the skilled person. All stereoisomers and mixtures thereof are included within the scope of the invention.

As used herein, references to halo and/or halogen will independently refer to fluoro, chloro, bromo and iodo (for example, fluoro and chloro).

25 Unless otherwise specified,  $C_{1-z}$  alkyl groups (where  $z$  is the upper limit of the range) defined herein may be straight-chain or, when there is a sufficient number (i.e. a minimum of two or three, as appropriate) of carbon atoms, be branched-chain, and/or cyclic (so forming a  $C_{3-z}$  cycloalkyl group). When there is a sufficient number (i.e. a minimum of four) 30 of carbon atoms, such groups may also be part cyclic (so forming a  $C_{3-z}$  partial cycloalkyl group). Part cyclic alkyl groups that may be mentioned include cyclopropylmethyl and cyclohexylethyl. When there is a sufficient number of carbon atoms, such groups may also be multicyclic (e.g. bicyclic or tricyclic) or spirocyclic.

35 Unless otherwise specified,  $C_{2-z}$  alkenyl groups (where  $z$  is the upper limit of the range) defined herein may be straight-chain or, when there is a sufficient number (i.e. a minimum of three) of carbon atoms, be branched-chain, and/or cyclic (so forming a  $C_{4-z}$  cycloalkenyl

group). When there is a sufficient number (i.e. a minimum of five) of carbon atoms, such groups may also be part cyclic. Part cyclic alkenyl groups that may be mentioned include cyclopentenylmethyl and cyclohexenylmethyl. When there is a sufficient number of carbon atoms, such groups may also be multicyclic (e.g. bicyclic or tricyclic) or spirocyclic.

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Unless otherwise specified,  $C_{2-z}$  alkynyl groups (where  $z$  is the upper limit of the range) defined herein may be straight-chain or, when there is a sufficient number (i.e. a minimum of four) of carbon atoms, be branched-chain.

10 For the avoidance of doubt, the skilled person will understand that the term alkyl will refer to saturated hydrocarbon moieties, whereas the term alkenyl will refer to unsaturated hydrocarbon moieties containing at least one carbon-carbon double bond and the term alkynyl will refer to unsaturated hydrocarbon moieties containing at least one carbon-carbon triple bond, which alkyl, alkenyl and alkynyl groups may be referred to collectively 15 as hydrocarbyl groups. Further, such unsaturated hydrocarbon moieties will be referred to by reference to the highest degree of unsaturation comprised therein (e.g. a hydrocarbon moiety comprising at least one carbon-carbon double bond and at least one carbon-carbon triple bond will be referred to as alkynyl, although such moieties may also be referred to using terms such as "alkenyl alkynyl" and the like).

20

As used herein, the term heterocyclyl may refer to non-aromatic monocyclic and bicyclic heterocyclyl groups (which groups may further be bridged) in which at least one (e.g. one to four) of the atoms in the ring system is other than carbon (i.e. a heteroatom), and in which the total number of atoms in the ring system is between three and twelve (e.g. 25 between five and ten and, most preferably, between three and eight, e.g. a 5- or 6-membered heterocyclyl group). Further, such heterocyclyl groups may be saturated, forming a heterocycloalkyl, or unsaturated containing one or more carbon-carbon or, where possible, carbon-heteroatom or heteroatom-heteroatom double and/or triple bonds, forming for example a  $C_{2-z}$  (e.g.  $C_{4-z}$ ) heterocycloalkenyl (where  $z$  is the upper limit of the 30 range) or a  $C_{7-z}$  heterocycloalkynyl group.  $C_{2-z}$  heterocyclyl groups that may be mentioned include 7-azabicyclo-[2.2.1]heptanyl, 6-azabicyclo[3.1.1]heptanyl, 6-azabicyclo[3.2.1]-octanyl, 8-azabicyclo[3.2.1]octanyl, aziridinyl, azetidinyl, 2,3-dihydroisothiazolyl, dihydropyranyl, dihydropyridinyl, dihydropyrrolyl (including 2,5-dihydropyrrolyl), dioxolanyl (including 1,3-dioxolanyl), dioxanyl (including 1,3-dioxanyl and 1,4-dioxanyl), dithianyl (including 1,4-dithianyl), dithiolanyl (including 1,3-dithiolanyl), imidazolidinyl, imidazolinyl, isothiazolidinyl, morpholinyl, 7-oxabicyclo[2.2.1]heptanyl, 6-oxabicyclo[3.2.1]-octanyl, oxetanyl, oxiranyl, piperazinyl, piperidinyl, pyranyl, pyrazolidinyl, pyrrolidinonyl,

pyrrolidinyl, pyrrolinyl, quinuclidinyl, sulfolanyl, 3-sulfolenyl, tetrahydropyrananyl, tetrahydrofuryl, tetrahydropyridinyl (such as 1,2,3,4-tetrahydropyridinyl and 1,2,3,6-tetrahydropyridinyl), thietanyl, thiiranyl, thiolanyl, tetrahydrothiopyrananyl, thiomorpholinyl, trithianyl (including 1,3,5-trithianyl), tropanyl and the like. Substituents on heterocyclyl groups may, where appropriate, be located on any atom in the ring system including a heteroatom. Further, in the case where the substituent is another cyclic compound, then the cyclic compound may be attached through a single atom on the heterocyclyl group, forming a so-called "spiro"-compound. The point of attachment of heterocyclyl groups may be *via* any atom in the ring system including (where appropriate) a further heteroatom (such as a nitrogen atom), or an atom on any fused carbocyclic ring that may be present as part of the ring system. Heterocyclyl groups may also be in the *N*- or *S*- oxidised form.

At each occurrence when mentioned herein, particular heterocyclyl groups that may be mentioned include 3- to 8-membered heterocyclyl groups (e.g. a 4- to 6-membered heterocyclyl group).

As may be used herein, the term aryl includes references to C<sub>6-14</sub> (e.g. C<sub>6-10</sub>) aromatic groups. Such groups may be monocyclic or bicyclic and, when bicyclic, be either wholly or partly aromatic. C<sub>6-10</sub> aryl groups that may be mentioned include phenyl, naphthyl, 1,2,3,4-tetrahydronaphthyl, indanyl, and the like (e.g. phenyl, naphthyl and the like, such as phenyl). For the avoidance of doubt, the point of attachment of substituents on aryl groups may be *via* any carbon atom of the ring system.

As may be used herein, the term heteroaryl (or heteroaromatic) includes references to 5- to 14- (e.g. 5- to 10-, such as 5- or 6-) membered heteroaromatic groups (as may be specified) containing one or more heteroatoms selected from oxygen, nitrogen and/or sulfur. Where possible, such heteroaryl groups may comprise one, two, or three rings, of which at least one is aromatic. Substituents on heteroaryl/heteroaromatic groups may, where appropriate, be located on any atom in the ring system including a heteroatom. Unless otherwise specified, the point of attachment of heteroaryl/heteroaromatic groups may be *via* any atom in the ring system including (where appropriate) a heteroatom. Bicyclic heteroaryl/heteroaromatic groups may comprise a benzene ring fused to one or more further aromatic or non-aromatic heterocyclic rings, in which instances, the point of attachment of the polycyclic heteroaryl/heteroaromatic group may be *via* any ring including the benzene ring or the heteroaryl/heteroaromatic or heterocyclyl ring. Examples of heteroaryl/heteroaromatic groups that may be mentioned include pyridinyl, pyrrolyl, furanyl, thiophenyl, oxadiazolyl, thiadiazolyl, thiazolyl, oxazolyl, pyrazolyl, triazolyl,

tetrazolyl, isoxazolyl, isothiazolyl, imidazolyl, imidazopyrimidinyl, imidazothiazolyl, thienothiophenyl, pyrimidinyl, furopyridinyl, indolyl, azaindolyl, pyrazinyl, pyrazolopyrimidinyl, indazolyl, pyrimidinyl, quinolinyl, isoquinolinyl, quinazolinyl, benzofuranyl, benzothiophenyl, benzoimidazolyl, benzoxazolyl, benzothiazolyl, 5  
benzotriazolyl and purinyl. The oxides of heteroaryl/ heteroaromatic groups are also embraced within the scope of the invention (e.g. the *N*-oxide). As stated above, heteroaryl includes polycyclic (e.g. bicyclic) groups in which one ring is aromatic (and the other may or may not be aromatic). Hence, other heteroaryl groups that may be mentioned include e.g. benzo[1,3]dioxolyl, benzo[1,4]dioxinyl, dihydrobenzo[d]isothiazole, 10 3,4-dihydrobenz[1,4]oxazinyl, dihydrobenzothiophenyl, indolinyl, 5H,6H,7H-pyrrolo[1,2-*b*]pyrimidinyl, 1,2,3,4-tetrahydroquinolinyl, thiochromanyl and the like.

For the avoidance of doubt, as used herein, references to heteroatoms will take their normal meaning as understood by one skilled in the art. Particular heteroatoms that may 15 be mentioned include phosphorus, selenium, tellurium, silicon, boron, oxygen, nitrogen and sulfur (e.g. oxygen, nitrogen and sulfur).

For the avoidance of doubt, references to polycyclic (e.g. bicyclic) groups (e.g. when employed in the context of heterocycl groups) will refer to ring systems wherein more 20 than two scissions would be required to convert such rings into a straight chain, with the minimum number of such scissions corresponding to the number of rings defined (e.g. the term bicyclic may indicate that a minimum of two scissions would be required to convert the rings into a straight chain). For the avoidance of doubt, the term bicyclic (e.g. when employed in the context of heterocycl groups) may refer to groups in which the second 25 ring of a two-ring system is formed between two adjacent atoms of the first ring, and may also refer to groups in which two non-adjacent atoms are linked by either an alkylene or heteroalkylene chain (as appropriate), which later groups may be referred to as bridged.

For the avoidance of doubt, when an aryl or an heteroaryl group is substituted with a group 30 via a double bond, such as =O, it is understood that the aryl or heteroaryl group is partly aromatic, i.e. the aryl or heteroaryl group consists of at least two rings where at least one ring is not aromatic.

The present invention also embraces isotopically-labelled compounds of the present 35 invention which are identical to those recited herein, but for the fact that one or more atoms are replaced by an atom having an atomic mass or mass number different from the atomic mass or mass number usually found in nature (or the most abundant one found in nature).

All isotopes of any particular atom or element as specified herein are contemplated within the scope of the compounds of the invention. Hence, the compounds of the invention also include deuterated compounds, i.e. in which one or more hydrogen atoms are replaced by the hydrogen isotope deuterium.

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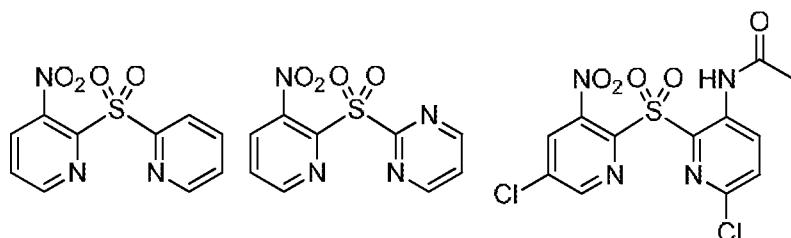
For the avoidance of doubt, in cases in which the identity of two or more substituents in a compound of the invention may be the same, the actual identities of the respective substituents are not in any way interdependent. For example, in the situation in which two or more Y groups are present, those Y groups may be the same or different. Similarly, 10 where two or more Y groups are present and each represent R<sup>a2</sup>, the R<sup>2a</sup> groups in question may be the same or different. Likewise, when more than one R<sup>a1</sup> is present and each independently represents C<sub>1-6</sub> alkyl substituted by one or more G<sup>1a</sup> group, the identities of each G<sup>1a</sup> are in no way interdependent.

15 For the avoidance of doubt, when a term such as "A<sup>a1</sup> to A<sup>f1</sup>" is employed herein, this will be understood by the skilled person to mean A<sup>a1</sup>, A<sup>b1</sup>, A<sup>c1</sup>, A<sup>d1</sup>, A<sup>e1</sup> and A<sup>f1</sup> inclusively. Unless otherwise stated, the same reasoning will apply to other such terms used herein.

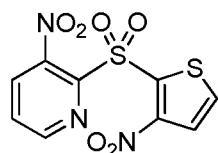
20 The skilled person will appreciate that compounds of the invention that are the subject of this invention include those that are stable. That is, compounds of the invention include those that are sufficiently robust to survive isolation, e.g. from a reaction mixture, to a useful degree of purity.

25 All embodiments of the invention and particular features mentioned herein may be taken in isolation or in combination with any other embodiments and/or particular features mentioned herein (hence describing more particular embodiments and particular features as disclosed herein) without departing from the disclosure of the invention.

30 For the avoidance of doubt, the compounds listed in the provisos provided in the first aspect of the invention (and therefore excluded as compounds of formula I in the first aspect of the invention) may be represented structurally as follows:



and



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In particular embodiments of compounds of the invention (including compounds of the first aspect of the invention), the heteroaryl group representing X is a 5- to 6- membered heteroaryl group. Thus, in such embodiments, X represents a 5- to 6- heteroaryl group, attached to L via a carbon atom, optionally substituted by one or more groups 10 independently selected from Y.

For the avoidance of doubt, the skilled person will understand that 5- to 6- membered heteroaryl groups will be necessarily monocyclic.

15 Particular compounds of the invention that may be mentioned include those in which n represents 2.

Further compounds of the invention that may be mentioned include those in which n represents 1.

20 Particular compounds of the invention that may be mentioned (e.g. in relation to the first aspect of the invention) include those in which X is unsubstituted or substituted with one or two Y groups.

25 For example, particular compounds of the invention that may be mentioned include those in which X is unsubstituted.

Further compounds of the invention that may be mentioned include those in which X is substituted with one Y.

30 More particular compounds of the invention that may be mentioned include those in which each Y independently represents halo (such as fluoro or chloro),  $R^{a3}$ ,  $-N(R^{j3})R^{k3}$  or  $-OR^{l3}$ .

More particular compounds of the invention that may be mentioned include those in which:

each  $R^{a3}$  independently represents  $C_{1-6}$  alkyl (e.g. methyl) optionally substituted by one or more fluoro; and/or (e.g. and)

each  $R^{j3}$ ,  $R^{k3}$  and  $R^{l3}$  independently represents H, or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl (e.g.  $C_{1-6}$  alkyl) each optionally substituted by one or more fluoro.

5

More particular compounds of the invention that may be mentioned include those in which: X is unsubstituted or substituted with one Y;

each Y (i.e. where present) independently represents halo (such as fluoro or chloro),  $-N(R^{j3})R^{k3}$ ,  $-OR^{l3}$ , or  $R^{a3}$ ;

10 each  $R^{a3}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl (e.g.  $C_{1-6}$  alkyl, such as methyl) each optionally substituted by one or more fluoro; and/or (e.g. and)

each  $R^{j3}$ ,  $R^{k3}$  and  $R^{l3}$  independently represents H, or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl (e.g.  $C_{1-6}$  alkyl) each optionally substituted by one or more fluoro.

15 More particular compounds of the invention that may be mentioned include those in which: X is unsubstituted or substituted with one Y; and/or (e.g. and)

Y represents halo (e.g. fluoro or chloro)  $-OC_{1-6}$  alkyl,  $-OC_{2-6}$  alkenyl or  $-OC_{2-6}$  alkynyl (e.g.  $-OC_{1-6}$  alkyl) each optionally substituted by one or more fluoro (e.g.  $-OCH_3$ ), or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl (e.g.  $C_{1-6}$  alkyl) each optionally substituted by one or more fluoro

20 (e.g.  $-CH_3$ ).

Yet more particular compounds of formula I that may be mentioned include those in which:

X is unsubstituted or substituted with one Y; and/or (e.g. and)

Y represents fluoro, chloro, or  $C_{1-6}$  alkyl optionally substituted by one or more fluoro (e.g.  $-CH_3$ ).

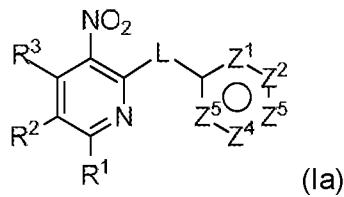
In certain embodiments of compounds of formula I, each Y (where present) represents methyl optionally substituted with one or more fluoro (e.g.  $-CH_3$ ).

30 Thus, examples of more particular compounds that may be mentioned include those in which:

X is unsubstituted or substituted with one Y; and/or (e.g. and)

Y represents methyl optionally substituted with one or more fluoro (e.g.  $-CH_3$ ).

35 In a particular embodiment (i.e. of compounds of the invention, e.g. compounds of the first aspect of the invention), the compound of formula I is a compound of formula Ia



wherein:

L, R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> and are defined for compounds of the invention (including all particular features and embodiments thereof);

each of Z<sup>1</sup> to Z<sup>5</sup> represents CR<sup>4</sup> to CR<sup>8</sup>, respectively, with the exception that one or two of Z<sup>1</sup> to Z<sup>5</sup> instead represents a heteroatom, which where possible may be substituted with R<sup>9</sup>, and optionally one of Z<sup>1</sup> to Z<sup>5</sup> may instead represent a direct bond; and

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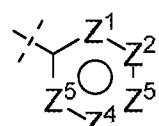
each of R<sup>4</sup> to R<sup>9</sup> represents H or Y as defined herein for compounds of the invention (including all particular features and embodiments thereof).

For the avoidance of doubt, where the compound of formula I (i.e. the compound of the invention) is a compound of formula Ia, compounds of the invention (e.g. compounds of the first aspect of the invention) include pharmaceutically acceptable salts of compounds of formula Ia.

For the avoidance of doubt, in compounds of formula Ia, the ring containing Z<sup>1</sup> to Z<sup>5</sup> is aromatic (as indicated by the presence of the circle inside that ring as depicted hereinabove).

For the avoidance of doubt, in relation to all compounds having such a group defined herein, the group X may be defined as a moiety of structural formula:

25



wherein the bond dissected by the dashed line is the bond forming the attachment to the required sulfonyl moiety, and wherein Z<sup>1</sup> to Z<sup>5</sup> are as defined herein for compounds of formula Ia (including all embodiments and features thereof).

In a particular embodiment of compounds of formula Ia, where  $Z^1$  to  $Z^5$  represents a heteroatom, which where possible may be substituted with  $R^9$ , that group may represent O, S, N or  $NR^9$ .

- 5 In a particular embodiment of compounds of formula Ia, each of  $Z^1$  to  $Z^5$  represents  $CR^4$  to  $CR^8$ , respectively, with the exception that one or two of  $Z^1$  and  $Z^3$  to  $Z^5$  instead represents a heteroatom, which where possible may be substituted with  $R^9$ , and optionally  $Z^3$  may instead represent a direct bond.
- 10 In a particular embodiment of compounds of formula Ia,  $R^9$  (where present) represents H.

Thus, in a particular embodiment of compounds of formula Ia, where  $Z^1$  to  $Z^5$  represents a heteroatom, which where possible may be substituted with  $R^9$ , that group may represent O, S, N or NH.

- 15 In a particular embodiment, each of  $R^4$  to  $R^9$  represents H with the exception that one or two (e.g. one) of  $R^4$  to  $R^9$  (e.g. one or two of  $R^4$  to  $R^8$ ) may optionally instead represent Y as defined herein for compounds of formula I (including all particular features and embodiments thereof).
- 20 In a more particular embodiment, each of  $R^4$ ,  $R^5$ ,  $R^7$ ,  $R^8$  and  $R^9$  (where present) represents H and  $R^6$  (where present) represents H or Y as defined for compounds of formula I (including all particular features and embodiments thereof).

- 25 In a yet more particular embodiment, each of  $R^4$ ,  $R^5$ ,  $R^7$ ,  $R^8$  and  $R^9$  (where present) represents H and  $R^6$  (where present) represents H or Y, wherein Y represents halo (e.g. fluoro or chloro),  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl (e.g.  $C_{1-6}$  alkyl) each optionally substituted by one or more fluoro (e.g.  $-CH_3$ ,  $-CHF_2$  or  $-CF_3$ ), or  $-OC_{1-6}$  alkyl,  $-OC_{2-6}$  alkenyl or  $-OC_{2-6}$  alkynyl (e.g.  $-OC_{1-6}$  alkyl) optionally substituted by one or more fluoro (e.g.  $-OCH_3$ ,  $-OCHF_2$  or  $-OCF_3$ ).

- 30 In a yet more particular embodiment, each of  $R^4$ ,  $R^5$ ,  $R^7$ ,  $R^8$  and  $R^9$  (where present) represents H and  $R^6$  (where present) represents H or Y, wherein Y represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl (e.g.  $C_{1-6}$  alkyl) each optionally substituted by one or more fluoro (e.g.  $-CH_3$ ,  $-CHF_2$  or  $-CF_3$ ).

In a yet more particular embodiment, each of R<sup>4</sup>, R<sup>5</sup>, R<sup>7</sup>, R<sup>8</sup> and R<sup>9</sup> (where present) represents H and R<sup>6</sup> (where present) represents H or Y, wherein Y represents methyl optionally substituted by one or more fluoro.

5 For example, particular compounds of formula I that may be mentioned include those in which X represents pyridinyl (e.g. 2-pyridinyl or 4-pyridinyl, such as 2-pyridinyl), pyrimidinyl (e.g. 2-pyrimidinyl or 4-pyrimidinyl, such as 2-pyrimidinyl), imidazolyl (e.g. 2-imidazolyl) and thiazolyl (e.g. 2-thiazolyl), each optionally substituted with one or more (e.g. one) Y group.

10

Thus, yet more particular compounds of formula I that may be mentioned include those in which X represents pyridinyl (e.g. 2-pyridinyl or 4-pyridinyl, such as 2-pyridinyl), pyrimidinyl (e.g. 2-pyrimidinyl), imidazolyl (e.g. 2-imidazolyl) and methyl thiazolyl (e.g. 4-methyl-2-thiazolyl).

15

For example, in particular embodiments, when X represents pyridinyl optionally substituted with one or more Y group, that pyridinyl is a 2-pyridinyl, particularly unsubstituted 2-pyridinyl.

20

Particular compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> each independently represents H, halo, R<sup>a1</sup>, -N(R<sup>j1</sup>)R<sup>k1</sup> or -OR<sup>l1</sup>.

25

More particular compounds of the invention that may be mentioned include those in which: each R<sup>a1</sup> and R<sup>f1</sup> independently represents C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl each optionally substituted by one or more groups independently selected from G<sup>1a</sup>, or heterocyclyl optionally substituted by one or more groups independently selected from G<sup>1b</sup>; and

30

each R<sup>b1</sup>, R<sup>c1</sup>, R<sup>d1</sup>, R<sup>e1</sup>, R<sup>g1</sup>, R<sup>h1</sup>, R<sup>i1</sup>, R<sup>j1</sup>, R<sup>k1</sup>, R<sup>l1</sup>, R<sup>m1</sup>, R<sup>n1</sup>, R<sup>o1</sup> and R<sup>p1</sup> independently represents H, C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl each optionally substituted by one or more groups independently selected from G<sup>1a</sup> or heterocyclyl optionally substituted by one or more groups independently selected from G<sup>1b</sup>; or

35

any of  $R^{c1}$  and  $R^{d1}$ ,  $R^{g1}$  and  $R^{h1}$  and/or  $R^{j1}$  and  $R^{k1}$  are linked together to form, together with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from halo, and  $C_{1-3}$  alkyl,  $C_{2-3}$  alkenyl or  $C_{2-3}$  alkynyl each optionally substituted by one or more halo, and =O.

More particular compounds of the invention that may be mentioned include those in which: each  $R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo,  $R^{a1}$ ,  $-N(R^{j1})R^{k1}$ ,  $-OR^{l1}$  or  $-SR^{m1}$  (e.g. H, halo,  $R^{a1}$ ,  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$ ); and/or (e.g. and) 10 each of  $R^{a1}$ ,  $R^{j1}$ ,  $R^{k1}$ ,  $R^{l1}$  and  $R^{m1}$  independently represents  $C_{1-6}$  alkyl (e.g. methyl) optionally substituted by one or more fluoro.

In certain embodiments that may be mentioned, only  $R^{c1}$  and  $R^{d1}$ , and/or  $R^{g1}$  and  $R^{h1}$  may alternatively be linked together in the manner described herein.

15 In more particular embodiments that may be mentioned,  $G^{1a}$  groups (i.e. where present as a substituent on  $R^{1a}$ , which in such instances may be alternatively referred to as  $G^{1ax}$  groups) may represent halo (e.g. fluoro).

20 In particular embodiments,  $R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo (e.g. fluoro or chloro, such as chloro),  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$ .

For example, particular compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments 25 thereof) that may be mentioned include those in which:

each  $R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo,  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$ ; and each  $R^{j1}$ ,  $R^{k1}$  and  $R^{l1}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl (e.g.  $C_{1-6}$  alkyl, such as  $C_{1-3}$  alkyl) each optionally substituted by one or more fluoro.

30 More particular compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which:

each  $R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo (e.g. fluoro or chloro, such as chloro),  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$ ; and

35 each  $R^{j1}$ ,  $R^{k1}$  and  $R^{l1}$  represents methyl optionally substituted by one or more fluoro.

Particular compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which R<sup>2</sup> and R<sup>3</sup> each represent H or fluoro.

5 More particular compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which R<sup>2</sup> and R<sup>3</sup> each represent H.

10 Particular compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which R<sup>1</sup> represents other than H.

15 Thus, in particular embodiments, compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which:

R<sup>2</sup> and R<sup>3</sup> each represent H; and

R<sup>1</sup> represents H or, particularly, halo (e.g. fluoro or chloro, such as chloro), -N(R<sup>j1</sup>)R<sup>k1</sup> or -OR<sup>l1</sup>, more particularly wherein each R<sup>j1</sup>, R<sup>k1</sup> and R<sup>l1</sup> represents C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl (e.g. C<sub>1-6</sub> alkyl or, particularly, C<sub>1-3</sub> alkyl, such as methyl) each optionally substituted by one or more fluoro.

20 In more particular embodiments, compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which:

25 R<sup>2</sup> and R<sup>3</sup> each represent H;

R<sup>1</sup> represents halo (e.g. fluoro or chloro, such as chloro), -N(R<sup>j1</sup>)R<sup>k1</sup> or -OR<sup>l1</sup>; and each R<sup>j1</sup>, R<sup>k1</sup> and R<sup>l1</sup> represents methyl optionally substituted by one or more fluoro.

30 In certain embodiments, compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which R<sup>1</sup> represents -OC<sub>1-3</sub> alkyl optionally substituted with one or more fluoro.

35 In further embodiments, compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which R<sup>1</sup> represents -OCH<sub>3</sub>.

Thus, in particular embodiments, compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof) that may be mentioned include those in which:

R<sup>2</sup> and R<sup>3</sup> each represent H; and

5 R<sup>1</sup> represents -OCH<sub>3</sub>.

As indicated herein above, particular features and embodiments as described herein may be combined without departing from the teaching of the invention.

10 For example, in a particular embodiments of compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof):

X represents a 5- to 6-membered heteroaryl group, attached to L via a carbon atom, optionally substituted by one or more (particularly, one or two) groups independently selected from Y;

15 each Y independently represents halo (such as fluoro or chloro, e.g. chloro), R<sup>a3</sup>, -N(R<sup>b3</sup>)R<sup>k3</sup> or -OR<sup>b3</sup>; and

each R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> each independently represents H, halo, R<sup>a1</sup>, -N(R<sup>j1</sup>)R<sup>k1</sup> or -OR<sup>l1</sup>.

20 In further such embodiments of compounds of the invention (e.g. compounds of the first aspect of the invention, including formula I and Ia, and all particular features and embodiments thereof):

X represents a 5- to 6-membered heteroaryl group, attached to L via a carbon atom, optionally substituted by one Y group;

25 Y represents methyl optionally substituted with one or more fluoro (e.g. -CH<sub>3</sub>);

R<sup>2</sup> and R<sup>3</sup> each represent H;

R<sup>1</sup> represents H or, particularly, halo (e.g. fluoro or chloro, such as chloro), -N(R<sup>j1</sup>)R<sup>k1</sup> or -OR<sup>l1</sup>; and

each R<sup>j1</sup>, R<sup>k1</sup> and R<sup>l1</sup> represents C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl (e.g. C<sub>1-3</sub> alkyl, such as methyl) each optionally substituted by one or more fluoro.

For the avoidance of doubt, the skilled person will understand that each G<sup>3c</sup> and G<sup>3d</sup> may be construed relative to G<sup>3a</sup> and G<sup>3b</sup> in the same manner as the corresponding G<sup>2c</sup> and G<sup>2d</sup> groups are construed relative to G<sup>2a</sup> and G<sup>2b</sup>, i.e. such that:

35 G<sup>3c</sup> and G<sup>3d</sup> independently representing halo, R<sup>a5</sup>, -CN, -A<sup>a4</sup>-C(Q<sup>a4</sup>)R<sup>b5</sup>, -A<sup>b4</sup>-C(Q<sup>b4</sup>)N(R<sup>c5</sup>)R<sup>d5</sup>, -A<sup>c4</sup>-C(Q<sup>c4</sup>)OR<sup>e5</sup>, -A<sup>d5</sup>-S(O)<sub>q</sub>R<sup>f5</sup>, -A<sup>e4</sup>-S(O)<sub>q</sub>N(R<sup>g5</sup>)R<sup>h5</sup>, -A<sup>f4</sup>-S(O)<sub>q</sub>OR<sup>i5</sup>, -N<sub>3</sub>, -N(R<sup>j5</sup>)R<sup>k5</sup>, -N(H)CN, -NO<sub>2</sub>, -ONO<sub>2</sub>, -OR<sup>l5</sup> or -SR<sup>m5</sup>,

each  $Q^{a4}$  to  $Q^{c4}$  independently represents  $=O$ ,  $=S$ ,  $=NR^{n5}$  or  $=N(OR^{o5})$ ;  
each  $A^{a4}$  to  $A^{f4}$  independently represents a single bond,  $-N(R^{p5})-$  or  $-O-$ ;  
with each  $R^{f5}$  to  $R^{p5}$  independently representing H, or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl  
each optionally substituted by one or more groups independently selected from  $G^4$ , or with  
5 each  $R^{g5}$  and  $R^{h5}$ , and  $R^{j5}$  and  $R^{k5}$  being linked together to form, together with the nitrogen  
atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains  
one further heteroatom and which ring optionally is substituted by one or more groups  
independently selected from  $G^4$ .

10 Particular compounds of the invention (including compounds of formula I and Ia, and all  
embodiments and particular forms thereof) that may be mentioned include the compounds  
of the examples as provided herein, or a pharmaceutically acceptable salt thereof.

15 Where an example compound is indicated to have been obtained in a particular salt form,  
the skilled person will understand that particular compounds of the invention that may be  
mentioned include the free base or free acid (as appropriate) of that compound, and *vice  
versa*. Further, where an example compound is indicated to have been obtained in a  
particular salt form, particular compounds of the invention that may be mentioned include  
other (i.e. different) pharmaceutically acceptable salts of that compound.

20 Thus, for the avoidance of doubt, particular compounds of the invention that may be  
mentioned include:

25 6-methoxy-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine;  
6-chloro-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine;  
6-dimethylamino-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine;  
30 6-methoxy-3-nitro-2-(pyridin-4-ylsulfonyl)pyridine;  
2-((6-methoxy-3-nitropyridin-2-yl)sulfonyl)pyrimidine;  
2-((1*H*-imidazol-2-yl)sulfonyl)-6-methoxy-3-nitropyridine; and  
2-((6-methoxy-3-nitropyridin-2-yl)sulfonyl)-4-methylthiazole,

and pharmaceutically acceptable salts thereof.

#### Compositions and medical uses

35 As discussed hereinbefore, compounds of the invention, and therefore compositions and  
kits comprising the same, are useful as pharmaceuticals.

According to a second aspect of the invention there is provided a compound of the invention, as hereinbefore defined (i.e. in the first aspect of the invention, including all embodiments and particular features therein, but without the provisos), for use as a 5 pharmaceutical. Further, there is provided a compound of the invention, as hereinbefore defined, for use in medicine.

In a particular embodiment of the second aspect of the invention, the compound of the invention is a compound of the first aspect of the invention (i.e. including the provisos).

10 As indicated herein, compounds of the invention may be of particular use in treating cancers.

15 Thus, in a third aspect of the invention, there is provided a compound of the invention, as hereinbefore defined (i.e. in the first aspect of the invention, including all embodiments and particular features therein, but without the provisos), for use in the treatment of cancer.

20 In an alternative third aspect of the invention, there is provided the use of a compound of the invention, as hereinbefore defined, in the manufacture of a medicament for the treatment of cancer.

In a further alternative third aspect of the invention, there is provided a method of treating cancer comprising administering to a patient in need thereof a therapeutically effective amount of a compound of the invention.

25 In a particular embodiment of the third aspect of the invention, the compound of the invention is a compound of the first aspect of the invention (i.e. including the provisos).

30 The skilled person will understand that references to the treatment of a particular condition (or, similarly, to treating that condition) take their normal meanings in the field of medicine. In particular, the terms may refer to achieving a reduction in the severity of one or more clinical symptom associated with the condition. For example, in the case of a cancer, the term may refer to achieving a reduction of the amount of cancerous cells present (e.g. in the case of a cancer forming a solid tumour, indicated by a reduction in tumour volume).

35 As used herein, references to patients will refer to a living subject being treated, including mammalian (e.g. human) patients.

As used herein, the term effective amount will refer to an amount of a compound that confers a therapeutic effect on the treated patient. The effect may be objective (i.e. measurable by some test or marker) or subjective (i.e. the subject gives an indication of and/or feels an effect).  
5

Although compounds of the invention may possess pharmacological activity as such, certain pharmaceutically-acceptable (e.g. "protected") derivatives of compounds of the invention may exist or be prepared which may not possess such activity, but may be  
10 administered parenterally or orally and thereafter be metabolised in the body to form compounds of the invention. Such compounds (which may possess some pharmacological activity, provided that such activity is appreciably lower than that of the active compounds to which they are metabolised) may therefore be described as "prodrugs" of compounds of the invention.

15 As used herein, references to prodrugs will include compounds that form a compound of the invention, in an experimentally-detectable amount, within a predetermined time, following enteral or parenteral administration (e.g. oral or parenteral administration). All prodrugs of the compounds of the invention are included within the scope of the invention.

20 Furthermore, certain compounds of the invention may possess no or minimal pharmacological activity as such, but may be administered parenterally or orally, and thereafter be metabolised in the body to form compounds of the invention that possess pharmacological activity as such. Such compounds (which also includes compounds that  
25 may possess some pharmacological activity, but that activity is appreciably lower than that of the active compounds of the invention to which they are metabolised), may also be described as "prodrugs".

30 Thus, the compounds of the invention are useful because they possess pharmacological activity, and/or are metabolised in the body following oral or parenteral administration to form compounds that possess pharmacological activity.

Without wishing to be bound by theory, it is believed that compounds of the invention wherein n represents 1 may be metabolised *in vivo* to form corresponding compounds of  
35 the invention wherein n represents 2.

As indicated herein, the compounds of the invention may be useful in the treatment of cancer (i.e. particular cancers).

Particular cancers that may be mentioned include those selected from the group comprising:

soft tissue cancers, such as sarcoma (e.g. angiosarcoma, fibrosarcoma, rhabdomyosarcoma, liposarcoma), myxoma, rhabdomyoma, fibroma, lipoma and teratoma;

10 lung cancers, such as bronchogenic carcinoma (e.g. squamous cell, undifferentiated small cell, undifferentiated large cell, adenocarcinoma), alveolar (or bronchiolar) carcinoma, bronchial adenoma, sarcoma, lymphoma, chondromatous hamartoma, mesothelioma, including non-small cell lung cancer;

15 gastrointestinal cancers: such as esophageal cancers (e.g. squamous cell carcinoma, adenocarcinoma, leiomyosarcoma, lymphoma), stomach cancers (e.g. carcinoma, lymphoma, leiomyosarcoma), pancreatic cancers (e.g. ductal adenocarcinoma, insulinoma, glucagonoma, gastrinoma, carcinoid tumors, vipoma), small bowel cancers 20 (e.g. adenocarcinoma, lymphoma, carcinoid tumors, Kaposi's sarcoma, leiomyoma, hemangioma, lipoma, neurofibroma, fibroma), large bowel cancers (e.g. adenocarcinoma, tubular adenoma, villous adenoma, hamartoma, leiomyoma);

25 genitourinary tract cancers, such as cancer of the kidney (e.g. adenocarcinoma, Wilm's tumor (nephroblastoma), lymphoma, leukemia), bladder and urethra (e.g. squamous cell carcinoma, transitional cell carcinoma, adenocarcinoma), prostate (e.g. adenocarcinoma, sarcoma), testis (e.g. seminoma, teratoma, embryonal carcinoma, teratocarcinoma, choriocarcinoma, sarcoma, interstitial cell carcinoma, fibroma, fibroadenoma, adenomatoid tumors, lipoma);

30 liver cancers, such as hepatoma (e.g. hepatocellular carcinoma), cholangiocarcinoma, hepatoblastoma, angiosarcoma, hepatocellular adenoma, hemangioma;

35 bone cancers, such as osteogenic sarcoma (e.g. osteosarcoma), fibrosarcoma, malignant fibrous histiocytoma, chondrosarcoma, Ewing's sarcoma, malignant lymphoma (e.g. reticulum cell sarcoma), multiple myeloma, malignant giant cell tumor chordoma,

osteochondroma (e.g. osteocartilaginous exostoses), benign chondroma, chondroblastoma, chondromyxofibroma, osteoid osteoma and giant cell tumors;

cancers of the head and/or nervous system, such as cancer of the skull (e.g. osteoma, 5 hemangioma, granuloma, xanthoma, osteitis deformans), meninges (e.g. meningioma, meningiosarcoma, gliomatosis), brain (e.g. astrocytoma, medulloblastoma, glioma, ependymoma, germinoma (pinealoma), glioblastoma multiform, oligodendrogioma, schwannoma, retinoblastoma, congenital tumors), spinal cord (e.g. neurofibroma, meningioma, glioma, sarcoma);

10

gynecological cancers, such as cancers of the uterus (e.g. endometrial carcinoma), cervix (cervical carcinoma, pre-tumor cervical dysplasia), ovaries (e.g. ovarian carcinoma (serous cystadenocarcinoma, mucinous cystadenocarcinoma, unclassified carcinoma), granulosa-thecal cell tumors, Sertoli-Leydig cell tumors, dysgerminoma, malignant 15 teratoma), cancers of the vulva (e.g. squamous cell carcinoma, intraepithelial carcinoma, adenocarcinoma, fibrosarcoma, melanoma), vagina (e.g. clear cell carcinoma, squamous cell carcinoma, botryoid sarcoma (embryonal rhabdomyosarcoma)), fallopian tubes (e.g. carcinoma);

20

haematologic cancers, such as cancers of the blood and bone marrow (e.g. myeloid leukemia (acute and chronic), acute lymphoblastic leukemia, chronic lymphocytic leukemia, myeloproliferative diseases, multiple myeloma, myelodysplastic syndrome), Hodgkin's disease, non-Hodgkin's lymphoma (malignant lymphoma);

25

skin cancers, such as malignant melanoma, basal cell carcinoma, squamous cell carcinoma, Kaposi's sarcoma, moles dysplastic nevi, lipoma, angioma, dermatofibroma, keloids; neurofibromatosis and Adrenal glands; and

neuroblastomas.

30

As used herein, references to cancerous cells and the like will include references to a cell afflicted by any one of the above identified conditions.

More particular cancers that may be mentioned include those corresponding to the cell 35 lines used in the examples provided herein.

For example, particular cancers that may be mentioned include breast cancer (such as mammary adenocarcinoma, e.g. metastatic mammary adenocarcinoma) and/or glioblastoma (such as glioblastoma multiform).

5 More particular cancers that may be mentioned include:

head and neck cancer (such as throat cancer, e.g. pharyngeal squamous cell carcinoma); colon cancer (such as colorectal carcinoma);

skin cancer (such as epidermoid (skin) carcinoma);

10 gastrointestinal cancers (such as pancreatic cancer, e.g. pancreatic ductal carcinoma); breast cancer (such as mammary adenocarcinoma, e.g. metastatic mammary adenocarcinoma);

lung cancer (such as carcinoma); and

haematologic cancers (such as leukemia, e.g. acute monocytic leukemia).

15

In particular embodiments, the cancer is a solid tumor cancer.

In more particular embodiments, the cancer is selected from pancreatic cancer, ovarian cancer and colorectal cancer.

20

For example, in certain embodiments, the cancer is selected from colorectal cancer (including those processing Ras mutations), small cell lung cancer, non-small cell lung cancer (NSCLC), and glioma.

25

In other embodiments, the cancer is selected from non-small cell lung cancer, ovarian cancer, metastatic breast cancer, pancreatic cancer, hepatobiliary cancer (including hepatocellular cancer, bile duct cancer and cholangiocarcinoma), and gastric cancer.

30

In further embodiments, the cancer is selected from colorectal cancer (including Ras mutations), small cell lung cancer, non-small cell lung cancer, ovarian cancer, hepatobiliary cancer (including hepatocellular cancer, bile duct cancer and cholangiocarcinoma), gastric cancer, testicular cancer, and head and neck squamous cell carcinoma.

35

In certain embodiments of the present invention, the cancer is selected from leukemia (including acute myeloid leukemia, acute lymphoblastic leukemia, chronic myeloid

leukemia, and chronic lymphoid leukemia), lymphoma (including mantle cell lymphoma, Hodgkin's lymphoma and non-Hodgkin's lymphoma), and prostate cancer

The skilled person will understand that treatment with compounds of the invention may

5 further comprise (i.e. be combined with) further treatment(s) for the same condition. In particular, treatment with compounds of the invention may be combined with means for the treatment of cancer, such as treatment with one or more other therapeutic agent that is useful in the in the treatment of cancer and/or one or more physical method used in the treatment of cancer (such as treatment through surgery), as known to those skilled in the  
10 art.

In particular, treatment with compounds of the invention may be performed in patients who are being or have been (i.e. as part or of a treatment for the same condition, such as within a month of treatment with compounds of the invention, such as within two weeks, e.g.

15 within a week or, particularly, on the same day) treated with a therapeutic agent or physical method that is capable of causing (e.g. can be demonstrated to cause) an increase in reactive oxygen species.

For the avoidance of doubt, the skilled person will understand that therapeutic agents or

20 physical methods capable of causing (e.g. can be demonstrated to cause) an increase in reactive oxygen species may not necessarily be effective treatments *per se*, but will become effective when used in combination with compounds of the invention.

For the avoidance of doubt, the skilled person will understand that compounds of the

25 invention may also be used in combination with one or more other therapeutic agent that is useful in the in the treatment of cancer and/or one or more physical method used in the treatment of cancer (such as treatment through surgery) wherein such methods do not cause an increase in reactive oxygen species.

30 In particular, treatment with compounds of the invention may be performed in patients who are being or have been treated with radiotherapy.

Thus, there is also provided:

35 a method of treating cancer in a patient in need thereof wherein the patient is administered a therapeutically effective amount of a compound of the invention in combination with treatment by radiotherapy (i.e. concomitantly or sequentially); and

a compound of the invention for use in treating cancer in a patient who is also being treated with radiotherapy.

5 Compounds of the invention will normally be administered orally, intravenously, subcutaneously, buccally, rectally, dermally, nasally, tracheally, bronchially, sublingually, intranasally, topically, by any other parenteral route or *via* inhalation, in a pharmaceutically acceptable dosage form.

10 Compounds of the invention may be administered alone or may be administered by way of known pharmaceutical compositions/formulations, including tablets, capsules or elixirs for oral administration, suppositories for rectal administration, sterile solutions or suspensions for parenteral or intramuscular administration, and the like.

15 According to a fourth aspect of the invention there is thus provided a pharmaceutical composition/formulation comprising a compound of the invention as hereinbefore defined (i.e. in the first aspect of the invention, including all embodiments and particular features therein, but without the provisos), and optionally (e.g. in admixture with) one or more pharmaceutically acceptable adjuvant, diluent and/or carrier.

20 In a particular embodiment of the fourth aspect of the invention, the compound of the invention is a compound of the first aspect of the invention (i.e. including the provisos).

25 The skilled person will understand that references herein to compounds of the invention being for particular uses (and, similarly, to uses and methods of use relating to compounds of the invention) may also apply to pharmaceutical compositions comprising compounds of the invention as described herein.

30 Compounds of the invention may be administered in the form of tablets or capsules, e.g. time-release capsules that are taken orally. Alternatively, the compounds of the invention may be in a liquid form and may be taken orally or by injection. The compounds of the invention may also be in the form of suppositories, or, creams, gels, and foams e.g. that can be applied to the skin. In addition, they may be in the form of an inhalant that is applied nasally or *via* the lungs.

35 The skilled person will understand that compounds of the invention may act systemically and/or locally (i.e. at a particular site).

Compounds of the invention may be administered orally, intravenously, subcutaneously, buccally, rectally, dermally, nasally, tracheally, bronchially, by any other parenteral route or *via* inhalation, in a pharmaceutically acceptable dosage form. Alternatively, particularly 5 where compounds of the invention are intended to act locally, compounds of the invention may be administered topically.

Thus, in a particular embodiment, the pharmaceutical formulation is provided in a pharmaceutically acceptable dosage form, including tablets or capsules, liquid forms to be 10 taken orally or by injection, suppositories, creams, gels, foams, or inhalants (e.g. to be applied intranasally). For the avoidance of doubt, in such embodiments, compounds of the invention may be present as a solid (e.g. a solid dispersion), liquid (e.g. in solution) or in other forms, such as in the form of micelles.

15 In more particular embodiments, the pharmaceutical formulation is provided the form of a tablets or capsules, liquid forms to be taken orally or by injection (e.g. a form suitable for intravenous injection). In particular, injection may take place using conventional means, and may include the use of microneedles.

20 Depending on e.g. potency and physical characteristics of the compound of the invention (i.e. active ingredient), pharmaceutical formulations that may be mentioned include those in which the active ingredient is present in at least 1% (or at least 10%, at least 30% or at least 50%) by weight. That is, the ratio of active ingredient to the other components (i.e. the addition of adjuvant, diluent and carrier) of the pharmaceutical composition is at least 25 1:99 (or at least 10:90, at least 30:70 or at least 50:50) by weight.

As described herein, compounds of the invention may also be combined with one or more other (i.e. different, e.g. agents other than compounds of formula I) therapeutic agents that are useful in the treatment of cancer. Such combination products that provide for the 30 administration of a compound of the invention in conjunction with one or more other therapeutic agent may be presented either as separate formulations, wherein at least one of those formulations comprises a compound of the invention, and at least one comprises the other therapeutic agent, or may be presented (i.e. formulated) as a combined preparation (i.e. presented as a single formulation including a compound of the invention 35 and the one or more other therapeutic agent).

Thus, according to a fifth aspect of the invention, there is provided a combination product comprising:

(A) a compound of the invention as hereinbefore defined (i.e. in the first aspect of the invention, including all embodiments and particular features therein, but without the provisos); and

(B) one or more other therapeutic agent that is useful in the treatment of cancer, wherein each of components (A) and (B) is formulated in admixture, optionally with one or more a pharmaceutically-acceptable adjuvant, diluent or carrier.

10 In a sixth aspect of the invention there is provided a kit-of-parts comprising:

(a) a pharmaceutical formulation as hereinbefore defined (i.e. in the fourth aspect of the invention); and

(b) one or more other therapeutic agent that is useful in the treatment of cancer, optionally in admixture with one or more pharmaceutically-acceptable adjuvant, diluent or 15 carrier,

which components (a) and (b) are each provided in a form that is suitable for administration in conjunction (i.e. concomitantly or sequentially) with the other.

In particular embodiments of the fourth and fifth aspects of the invention, the compound of 20 the invention is a compound of the first aspect of the invention (i.e. including the provisos).

The skilled person will understand that compounds of the invention, and pharmaceutically-acceptable salts thereof, may be administered (for example, as formulations as described hereinabove) at varying doses, with suitable doses being readily determined by one of skill

25 in the art. Oral, pulmonary and topical dosages (and subcutaneous dosages, although these dosages may be relatively lower) may range from between about 0.01 µg/kg of body weight per day (µg/kg/day) to about 200 µg/kg/day, preferably about 0.01 to about 10 µg/kg/day, and more preferably about 0.1 to about 5.0 µg/kg/day. For example, when administered orally, treatment with such compounds may comprise administration of a

30 formulations typically containing between about 0.01 µg to about 2000 mg, for example between about 0.1 µg to about 500 mg, or between 1 µg to about 100 mg (e.g. about 20 µg to about 80 mg), of the active ingredient(s). When administered intravenously, the most

35 preferred doses will range from about 0.001 to about 10 µg/kg/hour during constant rate infusion. Advantageously, treatment may comprise administration of such compounds and compositions in a single daily dose, or the total daily dosage may be administered in divided doses of two, three or four times daily (e.g. twice daily with reference to the doses described herein, such as a dose of 10 mg, 20 mg, 30 mg or 40 mg twice daily).

In any event, the physician, or the skilled person, will be able to determine the actual dosage which will be most suitable for an individual patient, which is likely to vary with the route of administration, the type and severity of the condition that is to be treated, as well  
5 as the species, age, weight, sex, renal function, hepatic function and response of the particular patient to be treated. The above-mentioned dosages are exemplary of the average case; there can, of course, be individual instances where higher or lower dosage ranges are merited, and such are within the scope of this invention.

10 Preparation of compounds/compositions

Pharmaceutical compositions/formulations, combination products and kits as described herein may be prepared in accordance with standard and/or accepted pharmaceutical practice.

15 Thus, in a further aspect of the invention there is provided a process for the preparation of a pharmaceutical composition/formulation, as hereinbefore defined, which process comprises bringing into association a compound of the invention, as hereinbefore defined, with one or more pharmaceutically-acceptable adjuvant, diluent or carrier.

20 In further aspects of the invention, there is provided a process for the preparation of a combination product or kit-of-parts as hereinbefore defined, which process comprises bringing into association a compound of the invention, as hereinbefore defined, or a pharmaceutically acceptable salt thereof with the other therapeutic agent that is useful in  
25 the treatment of cancer, and at least one pharmaceutically-acceptable adjuvant, diluent or carrier.

As used herein, references to bringing into association will mean that the two components are rendered suitable for administration in conjunction with each other.

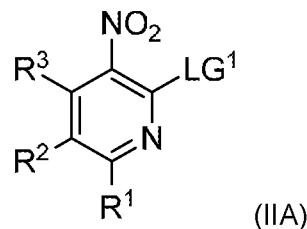
30 Thus, in relation to the process for the preparation of a kit of parts as hereinbefore defined, by bringing the two components "into association with" each other, we include that the two components of the kit of parts may be:  
35 (i) provided as separate formulations (i.e. independently of one another), which are subsequently brought together for use in conjunction with each other in combination therapy; or

(ii) packaged and presented together as separate components of a "combination pack" for use in conjunction with each other in combination therapy.

Compounds of the invention as described herein may be prepared in accordance with  
5 techniques that are well known to those skilled in the art, such as those described in the examples provided hereinafter.

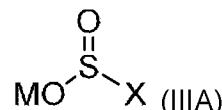
According to a seventh aspect of the invention there is provided a process for the preparation of a compound of the first aspect of the invention as hereinbefore defined (i.e.  
10 a compound of the invention but including the provisos), which process comprises:

(i) where n represents 2, reaction of a compound of formula IIA



15

wherein  $\text{R}^1$ ,  $\text{R}^2$  and  $\text{R}^3$  are as defined herein (i.e. for compounds of the invention, or any particular feature or embodiment thereof) and  $\text{LG}^1$  represents a suitable leaving group (such as halo, e.g. chloro), with a compound of formula IIIA

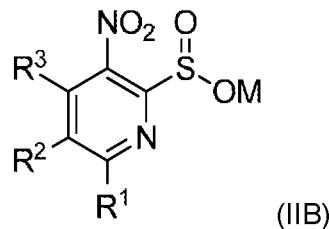


20

wherein  $\text{X}$  is as defined herein (i.e. for compounds of the invention, or any particular feature or embodiments thereof) and  $\text{M}$  represents an alkali metal ion (such as a  $\text{Na}^+$  ion), in the presence of a suitable acid (such as a concentrated acid, e.g. a concentrated mineral acid, for example concentrated  $\text{HCl}$ , e.g. concentrated aqueous  $\text{HCl}$ ) and in the presence of a suitable solvent (such as a polar organic solvent, e.g.  $\text{N,N}'$ -dimethylacetamide,  $\text{N,N}'$ -dimethylformamide or tetrahydrofuran), and optionally in the presence of a suitable phase transfer catalyst (such as a quaternary ammonium salt, e.g. *tetra*-butyl ammonium chloride);

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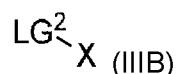
(ii) where n represents 2, particularly where at least one Y is present and represents an electron-withdrawing group (such as  $\text{-NO}_2$ ), reaction of a compound of formula IIB



5

wherein  $\text{R}^1$ ,  $\text{R}^2$  and  $\text{R}^3$  are as defined herein (i.e. for compounds of the invention, or any particular feature or embodiments thereof) and M represents an alkali metal ion (such as a Na ion), with a compound of formula IIIB

10



wherein X is as defined herein in formula I (i.e. for compounds of the invention, or any particular feature or embodiments thereof) and  $\text{LG}^2$  represents a suitable leaving group (such as halo, e.g. chloro), in the presence of a suitable acid (such as a concentrated acid,

15 e.g. a concentrated mineral acid, for example concentrated HCl, e.g. concentrated aqueous HCl) and in the presence of a suitable solvent (such as a polar organic solvent, e.g. *N,N*-dimethylacetamide, *N,N*'-dimethylformamide or tetrahydrofuran), and optionally in the presence of a suitable phase transfer catalyst (such as a quaternary ammonium salt, e.g. *tetra*-butyl ammonium chloride);

20

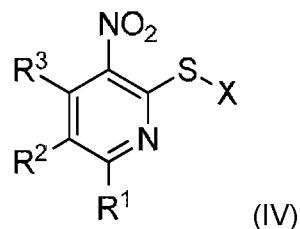
(iii) where n represents 2, reaction of a compound of formula IIA as hereinbefore defined with a compound of formula IIIA as hereinbefore defined, in the presence of a suitable metal halide (such as a suitable metal iodide, e.g.  $\text{CuI}$ , or a suitable metal bromide, e.g.  $\text{CuBr}$ ; which metal halide may be present in excess, such as in amount corresponding 25 to at least 2 molar equivalents of the compound of formula IIA and/or the compound of formula IIIA) and in the presence of a suitable solvent (such as a polar organic solvent, e.g. *N,N*'-dimethylacetamide, *N,N*'-dimethylformamide, tetrahydrofuran or 3-dimethyl-2-imidazolidinone), under conditions known to those skilled in the art;

30 (iv) where n represents 2, reaction of a compound of formula IIB as hereinbefore defined (particularly where at least one  $\text{R}^4$  is present and represents an electron-withdrawing group, such as  $\text{-NO}_2$ ) with a compound of formula IIIB as hereinbefore defined,

in the presence of a suitable metal halide (such as a suitable metal iodide, e.g. CuI, or a suitable metal bromide, e.g. CuBr; which metal halide may be present in excess, such as in amount corresponding to at least 2 molar equivalents of the compound of formula IIB and/or the compound of formula IIIB) and in the presence of a suitable solvent (such as a 5 polar organic solvent, e.g. *N,N'*-dimethylacetamide, *N,N'*-dimethylformamide, tetrahydrofuran or 3-dimethyl-2-imidazolidinone), under conditions known to those skilled in the art;

(v) reaction of a compound of formula IV

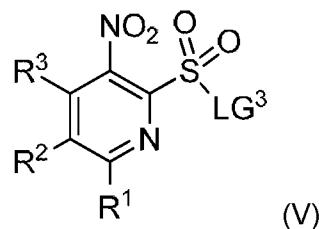
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wherein R<sup>1</sup> to R<sup>3</sup> and X are as defined herein (i.e. for compounds of the invention, or any particular feature or embodiments thereof), with a suitable oxidising agent (i.e. an oxidising 15 agent chosen and used in a manner as required to achieve the desired degree of oxidation; such as a hypochlorite salt, e.g. sodium hypochlorite, a peroxyomonosulfate salt, e.g. potassium peroxyomonosulfate (Oxone), a percarboxylic acid, e.g. *meta*-chloroperoxybenzoic acid (mCPBA), or potassium permanganate) in the presence of a suitable solvent (such as a polar organic solvent, e.g. *N,N'*-dimethylacetamide, *N,N'*-dimethylformamide or tetrahydrofuran), and optionally in the presence of water, under 20 conditions known to those skilled in the art;

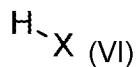
(vi) where n represents 2, particularly where one or more Y is present and represents an electron donating group (such as an alkyl group), reaction of a compound of formula V

25



wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are as defined herein (i.e. for compounds of the invention, or any particular feature or embodiments thereof) and LG<sup>3</sup> represents a suitable leaving group (such as halo, e.g. chloro) with a compound of formula VI

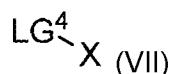
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wherein X is as defined (i.e. for compounds of the invention, or any particular feature or embodiments thereof), in the presence of a suitable Lewis acid (such as AlCl<sub>3</sub>) and in the presence of a suitable solvent (such as an organic solvent, e.g. dichloromethane or dichloroethane);

10 (vii) where n represents 2, reaction of a compound of formula V as defined herein with a compound of formula VI as defined herein (for example, where one or more Y group is present in the alpha position relative to the point of attachment to the sulfonyl group and represents a suitable directing group), in the presence of a suitable catalyst (such as palladium(II) acetate) and a suitable base (such as a alkali metal carbonate, e.g. potassium carbonate), and in the presence of a suitable solvent (such as an organic solvent, e.g. dichloromethane);

20 (viii) where n represents 2, reaction of a compound of formula V as defined herein with a compound of formula VII



25 wherein X is as defined herein (i.e. for compounds of the invention, or any particular feature or embodiments thereof) and LG<sup>4</sup> represents a suitable leaving group (such as a boronic acid), in the presence of a suitable catalyst (such as a suitable metal halide, e.g. CuBr, or phenanthroline) and in the presence of a suitable solvent (such as an organic solvent, e.g. dichloromethane or dichloroethane); or

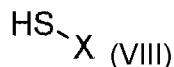
30

(ix) where n represents 2, reaction of a compound of formula IIB as defined herein with (a) a compound of formula VI as defined herein having at least one Y group, or (b) a compound of formula VI as defined herein but having a group that may be converted to a Y group, wherein the Y group or group that may be converted to a Y group is present in the alpha position relative to the essential H substituent and represents a suitable directing

group (such as a suitable amide, e.g.  $-\text{C}(\text{O})\text{N}(\text{H})\text{C}(\text{CH}_3)_2$ -2-pyridinyl), in the presence of a suitable catalyst and/or oxidant (such as copper(II) acetate and/or silver carbonate), and in the presence of a suitable solvent (such as an organic solvent, e.g. dichloroethane), which step may further comprise conversion of the group that may be converted to a Y 5 group to the required Y group, under conditions known to those skilled in the art.

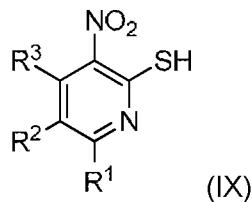
Compounds of formulae IIA, IIB, IIIA, IIIB, IV, V, VI and VII are either commercially available, are known in the literature, or may be obtained either by analogy with the processes described herein, or by conventional synthetic procedures, in accordance with 10 standard techniques, from available starting materials using appropriate reagents and reaction conditions. In this respect, the skilled person may refer to *inter alia* "Comprehensive Organic Synthesis" by B. M. Trost and I. Fleming, Pergamon Press, 1991. Further references that may be employed include "Heterocyclic Chemistry" by J. A. Joule, K. Mills and G. F. Smith, 3<sup>rd</sup> edition, published by Chapman & Hall, "Comprehensive 15 Heterocyclic Chemistry II" by A. R. Katritzky, C. W. Rees and E. F. V. Scriven, Pergamon Press, 1996 and "Science of Synthesis", Volumes 9-17 (Heterocyclic Compounds and Related Ring Systems), Georg Thieme Verlag, 2006.

In particular, compounds of formula IV may be prepared by reaction of a compound of 20 formula VIII



wherein X is as defined herein (i.e. for compounds of the invention, or any particular feature or embodiments thereof), with a compound of formula IIA as herein before defined, under 25 conditions known to those skilled in the art, such as in the presence of a suitable base (such as a metal carbonate, e.g. potassium carbonate, a metal hydroxide, e.g. sodium hydroxide, or an amine base, e.g. triethyl amine), and in the presence of a suitable solvent (such as a polar organic solvent, e.g. *N,N*'-dimethylacetamide, *N,N*'-dimethylformamide or tetrahydrofuran, or a mixture of a polar organic solvent and water), under conditions known 30 to those skilled in the art.

Similarly, compounds of formula IV (particularly where at least one Y is present and represents an electron-withdrawing group, such as  $-\text{NO}_2$ ) may be prepared by reaction of a compound of formula IX



wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are as defined herein (i.e. for compounds of the invention, or any particular feature or embodiments thereof), with a compound of formula IIIB as described herein, under conditions known to those skilled in the art (for example, where the R<sup>4</sup> groups present in the compound of formula IIIB are not sufficiently electron withdrawing, the reaction may be performed in the presence of a suitable catalyst, such as palladium(II) acetate or copper oxide, in which case the suitable base may be an alkali metal *tert*-butoxide, such as Kt-OBu).

10

Similarly, compounds of formulae VIII and IX are either commercially available, are known in the literature, or may be obtained either by analogy with the processes described herein, or by conventional synthetic procedures, in accordance with standard techniques, from available starting materials using appropriate reagents and reaction conditions.

15

The substituents R<sup>1</sup> to R<sup>3</sup> and Y (or, when the compound of formula I is defined as a compound of formula Ia, the substituents R<sup>1</sup> to R<sup>9</sup>), as hereinbefore defined, may be modified one or more times, after or during the processes described above for preparation of compounds of formula I (including compounds of formula Ia) by way of methods that are well known to those skilled in the art. Examples of such methods include substitutions, reductions, oxidations, dehydrogenations, alkylations, dealkylations, acylations, hydrolyses, esterifications, etherifications, halogenations and nitrations. The precursor groups can be changed to a different such group, or to the groups defined in formula I, at any time during the reaction sequence. The skilled person may also refer to "Comprehensive Organic Functional Group Transformations" by A. R. Katritzky, O. Meth-Cohn and C. W. Rees, Pergamon Press, 1995 and/or "Comprehensive Organic Transformations" by R. C. Larock, Wiley-VCH, 1999.

Compounds of the invention may be isolated from their reaction mixtures and, if necessary, purified using conventional techniques as known to those skilled in the art. Thus, processes for preparation of compounds of the invention as described herein may include, as a final step, isolation and optionally purification of the compound of the invention.

It will be appreciated by those skilled in the art that, in the processes described above and hereinafter, the functional groups of intermediate compounds may need to be protected by protecting groups. The protection and deprotection of functional groups may take place before or after a reaction in the above-mentioned schemes.

5

Protecting groups may be applied and removed in accordance with techniques that are well known to those skilled in the art and as described hereinafter. For example, protected compounds/intermediates described herein may be converted chemically to unprotected compounds using standard deprotection techniques. The type of chemistry involved will 10 dictate the need, and type, of protecting groups as well as the sequence for accomplishing the synthesis. The use of protecting groups is fully described in "*Protective Groups in Organic Synthesis*", 3rd edition, T.W. Greene & P.G.M. Wutz, Wiley-Interscience (1999).

10

In a further aspect of the invention, there is provided a compound of formula IV as defined 15 herein (i.e. wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> and X are as defined herein, including all particular features and embodiments thereof), or a pharmaceutically acceptable salt thereof.

Particular compounds of formula IV that may be mentioned include those prepared in the examples provided herein, and pharmaceutically acceptable salts thereof.

20

Compounds of the invention may have the advantage that they may be more efficacious than, be less toxic than, be longer acting than, be more potent than, produce fewer side effects than, be more easily absorbed than, and/or have a better pharmacokinetic profile (e.g. higher oral bioavailability and/or lower clearance) than, and/or have other useful 25 pharmacological, physical, or chemical properties over, compounds known in the prior art, whether for use in the above-stated indications or otherwise. In particular, compounds of the invention may have the advantage that they are more efficacious and/or exhibit advantageous properties *in vivo*.

30

Without wishing to be bound by theory, it is thought that inhibition of thioredoxin reductase is obtained by the utilization of strong electrophilicity of small molecule inhibitors in combination with a pronounced inherent nucleophilicity of NADPH-reduced, but not oxidized, thioredoxin reductase, resulting in selective and potent inhibition of said enzyme without major targeting of other cellular pathways or enzymes.

35

Moreover, it is thought that normal non-cancerous cells may survive without a functional cytosolic thioredoxin reductase enzyme because of maintained function of the glutathione

system, while cancer cells cannot survive upon specific inhibition of cytosolic thioredoxin reductase.

## Examples

The invention is illustrated by way of the following examples, in which the following abbreviations may be employed.

5

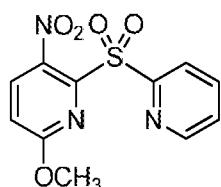
aq	aqueous	
BSA	bovine serum albumin	
conc	concentrated	
DMA	<i>N,N'</i> -dimethylacetamide	
10	DMF	<i>N,N'</i> -dimethylformamide
DMSO	dimethyl sulfoxide	
DTNB	5,5'-dithio-bis-(2-nitrobenzoic acid)	
EDTA	ethylenediaminetetraacetic acid	
GSSG	glutathione disulfide	
15	HPLC	high performance liquid chromatography
HRMS	high resolution mass spectrometry	
mCPBA	<i>meta</i> -chloroperbenzoic acid	
NADPH	nicotinamide adenine dinucleotide phosphate	
NMR	nuclear magnetic resonance	
20	PBS	phosphate buffered saline
rt	room temperature	

Starting materials and chemical reagents specified in the syntheses described below are commercially available from a number of suppliers, such as Sigma Aldrich.

25

In the event that there is a discrepancy between nomenclature and the structure of compounds as depicted graphically, it is the latter that presides (unless contradicted by any experimental details that may be given and/or unless it is clear from the context). The names of the final compounds may be translated to the structures e.g. using 30 ChemBioDraw Ultra 14.

### Example 1: 6-Methoxy-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine



(a) 6-Methoxy-3-nitro-2-(pyridin-2-ylthio)pyridine

A mixture of 2-chloro-6-methoxy-3-nitropyridine (0.25 g, 1.33 mmol), 2-mercaptopypyridine (0.16 g, 1.46 mmol),  $K_2CO_3$  (0.22 g, 1.62 mmol) and DMF (1 mL) was stirred at rt for 0.5 h. The mixture was poured into water and filtered to give the sub-title compound (0.34 g, 98 %).

(b) 6-Methoxy-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine

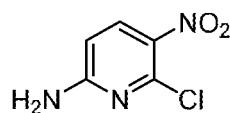
10  $NaOCl$  (aq, 10%, 1.71 mL, 2.86 mmol) was added dropwise to a stirred mixture of 6-methoxy-3-nitro-2-(pyridin-2-ylthio)pyridine (0.34 g, 1.30 mmol), glacial acetic acid (0.10 mL, 1.67 mmol) and DMF (1 mL) at rt. The mixture was stirred at rt for 4 h and poured into water. The pH was adjusted to ~9 with aq  $NaOH$  (20% (w/v)). After stirring for 30 seconds the precipitate was collected and washed with water. The solid was recrystallized from  $H_2O/EtOH$  (4:1) to give the title compound (0.12 g, 31 %).

15  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta$  8.74-8.67 (1H, m), 8.31-8.24 (2H, m), 8.08-8.00 (1H, m), 7.61-7.54 (1H, m), 7.01-6.96 (1H, m), 3.65 (3H, s);  
 $^{13}C$ -NMR (100 MHz,  $CDCl_3$ )  $\delta$  164.2, 157.4, 150.3, 150.2, 138.1, 136.9, 127.5, 124.0, 115.3, 55.2;  
ESI-MS:296 [M+H]<sup>+</sup>.

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Example 2: 6-Chloro-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine

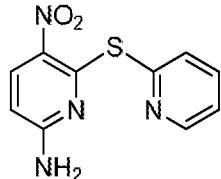
25 (a) 6-Chloro-5-nitropyridin-2-amine



Conc.  $HNO_3$  (2.39 mL, 35.00 mmol) was added dropwise to a mixture of conc  $H_2SO_4$  (56 mL, 1050 mmol) and 6-chloropyridin-2-amine (3.00 g, 23.34 mmol) at 0 °C. The mixture was stirred at 0 °C for 4 h and poured into ice-water. The mixture was extracted with  $EtOAc$  (3x100 mL). The combined organic layers were dried over anhydrous  $Na_2SO_4$  and

concentrated. The residue was purified by chromatography to give the sub-title compound (1.38 g, 34 %).

5 (b) 5-Nitro-6-(pyridin-2-ylthio)pyridin-2-amine



A mixture of 6-chloro-5-nitropyridin-2-amine (0.26 g, 1.50 mmol), 2-mercaptopypyridine (0.18 g, 1.65 mmol),  $K_2CO_3$  (0.25 g, 1.83 mmol) and DMF (2.1 mL) was stirred at 80 °C for 3.5

10 h. The mixture was poured into water and extracted with  $CH_2Cl_2$  (3x15 mL). The combined organic layers were dried over anhydrous  $Na_2SO_4$  and concentrated. The residue was dissolved in  $CH_2Cl_2$ , and the product was precipitated by addition of hexane to give the sub-title compound (0.27 g, 73 %).

15 (c) 6-Chloro-3-nitro-2-(pyridin-2-ylthio)pyridine



Isoamyl nitrite (0.26 mL, 1.93 mmol) was added to a stirred mixture of 5-nitro-6-(pyridin-2-

20 ylthio)pyridin-2-amine (0.24 g, 0.97 mmol),  $CuCl_2$  (0.26 g, 1.93 mmol) and MeCN (5 mL) at rt. The mixture was stirred at 60 °C for 14 h, poured into acidic water (1N HCl, 4 mL) and extracted with EtOAc (3x15 mL). The combined organic layers were washed with saturated aq  $NaHCO_3$  (10 mL), brine (10 mL) and dried over anhydrous  $Na_2SO_4$  and concentrated. The residue was purified by chromatography to give the sub-title compound

25 (0.08 g, 32 %).

(d) 6-Chloro-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine

mCPBA (0.17 g, 0.67 mmol) was added in portions to a stirred mixture of 6-chloro-3-nitro-

30 2-(pyridin-2-ylthio)pyridine (0.08 g, 0.31 mmol) and  $CH_2Cl_2$  (8 mL) at 0 °C. The mixture was stirred at rt for 14 h and poured into saturated aq  $Na_2S_2O_3$  (3 mL) at 0 °C. The phases

were separated and the organic layer extracted with saturated aq  $\text{NaHCO}_3$  (2x5 mL) and brine (5 mL). The organic phase was dried over anhydrous  $\text{Na}_2\text{SO}_4$  and concentrated. The crude mixture was purified by chromatography to give the title compound (0.03 g, 29 %).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.67 (ddd,  $J$  = 4.7, 1.7, 0.9 Hz, 1H), 8.27 (dt,  $J$  = 7.9, 1.0 Hz,

5 1H), 8.24 (d,  $J$  = 8.4 Hz, 1H), 8.06 (td,  $J$  = 7.8, 1.7 Hz, 1H), 7.70 (d,  $J$  = 8.4 Hz, 1H), 7.59 (ddd,  $J$  = 7.7, 4.7, 1.1 Hz, 1H);

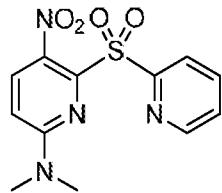
$^{13}\text{C}$ -NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  156.7, 153.7, 150.6, 150.3, 144.5, 138.3, 136.1, 129.2,

128.0, 123.8;

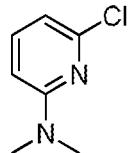
ESI-MS:300  $[\text{M}+\text{H}]^+$ .

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Example 3: 6-Dimethylamino-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine



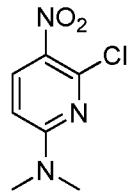
15 (a) 6-Chloro-*N,N*-dimethylpyridin-2-amine



A mixture of 2,6-dichloropyridine (2.20 g, 14.9 mmol) and DMF (11.5 mL, 148.7 mmol) was

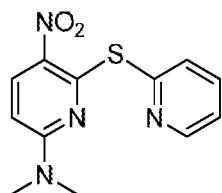
20 heated under microwave irradiation at 180 °C for 1 h. The mixture was poured into water and extracted with EtOAc (3x30 mL). The combined organic phases were dried over anhydrous  $\text{Na}_2\text{SO}_4$  and concentrated. The residue was purified by chromatography to give the sub-title compound (2.12 g, 91 %).

25 (b) 6-Chloro-*N,N*-dimethyl-5-nitropyridin-2-amine



Conc  $\text{HNO}_3$  (0.9 mL, 13.52 mmol) was added dropwise to a mixture of conc  $\text{H}_2\text{SO}_4$  (32.4 mL, 608.6 mmol) and 6-chloro-*N,N*-dimethylpyridin-2-amine (2.12 g, 13.5 mmol) at 0 °C. The mixture was stirred at 0 °C for 1.5 h and poured into ice-water. The mixture was extracted with  $\text{CH}_2\text{Cl}_2$  (3x100 mL). The combined organic layers were washed with 5 saturated aq  $\text{Na}_2\text{CO}_3$ , dried over anhydrous  $\text{Na}_2\text{SO}_4$  and concentrated. The residue was purified by chromatography to give the sub-title compound (0.89 g, 33 %).

10 (c) *N,N*-Dimethyl-5-nitro-6-(pyridin-2-ylthio)pyridin-2-amine



10

A mixture of 6-chloro-*N,N*-dimethyl-5-nitropyridin-2-amine (0.11 g, 0.55 mmol), 2-mercaptopypyridine (0.07 mg, 0.61 mmol),  $\text{K}_2\text{CO}_3$  (0.09 g, 0.67 mmol) and DMF (1 mL) was stirred at 80 °C for 1 h. The mixture was poured into water (150 mL), the precipitate 15 was collected, washed with water and dried to give the sub-title compound (0.12 g, 76 %).

(d) 6-Dimethylamino-3-nitro-2-(pyridin-2-ylsulfonyl)pyridine

mCPBA (0.22 g, 0.92 mmol) was added in portions to a stirred mixture of *N,N*-dimethyl-5-20 nitro-6-(pyridin-2-ylthio)pyridin-2-amine (0.12 g, 0.42 mmol) and  $\text{CH}_2\text{Cl}_2$  (8 mL) at 0 °C. The mixture was stirred at rt for 5 h and poured into saturated aq  $\text{K}_2\text{CO}_3$  (5 mL). The phases were separated and the aq layer extracted with  $\text{CH}_2\text{Cl}_2$ . The combined organic phases were washed with saturated aq  $\text{Na}_2\text{S}_2\text{O}_5$  and  $\text{NaHSO}_3$  mixture, dried over anhydrous  $\text{Na}_2\text{SO}_4$  and concentrated. The residue was recrystallized from  $\text{H}_2\text{O}/\text{EtOH}$  (1:9) 25 and additionally purified by chromatography to give the title compound (0.06 g, 44 %).

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.74-8.68 (1H, m), 8.27-8.23 (1H, m), 8.21 (1H, d,  $J$  = 9.4 Hz), 8.03-7.96 (1H, m), 7.55-7.49 (1H, m), 6.54 (1H, d,  $J$  = 9.4 Hz), 2.90 (6H, br s);

$^{13}\text{C}$ -NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  158.2, 157.9, 152.4, 149.9, 137.8, 136.0, 126.9, 124.0, 107.2, 38.2;

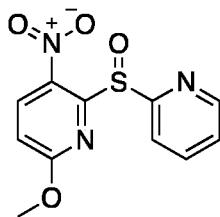
30 ESI-MS:309 [M+H]<sup>+</sup>.

The following example compounds were prepared from 2-chloro-6-methoxy-3-nitropyridine and the appropriate heteroarylthiol in accordance with the procedure in Example 1, Step a, and Example 2, Step d.

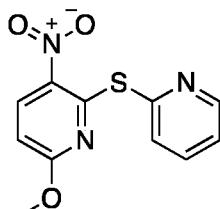
Ex.	Chemical structure	MS [m/z (M+H) <sup>+</sup> ]
	Name	
	<sup>1</sup> H-NMR [solvent, δ] <sup>13</sup> C-NMR [solvent, δ]	
4		<b>MS</b> [m/z (M+H) <sup>+</sup> =(Calculated for C <sub>11</sub> H <sub>9</sub> N <sub>3</sub> O <sub>5</sub> S+H: 296.04) found: 296.1]
	6-methoxy-3-nitro-2-(pyridin-4-ylsulfonyl)pyridine <sup>1</sup> H-NMR [DMSO-d <sub>6</sub> , δ 8.51 (d, J = 8 Hz, 1H), 8.29 (d, J = 7 Hz, 2H), 7.82 (d, J = 7 Hz, 2H), 7.16 (d, J = 8 Hz, 1H), 4.09 (s, 3H)]	
5		<b>MS</b> [m/z (M+H) <sup>+</sup> =(Calculated for C <sub>10</sub> H <sub>8</sub> N <sub>4</sub> O <sub>5</sub> S+H: 297.03) found: 297.1]
	2-((6-methoxy-3-nitropyridin-2-yl)sulfonyl)pyrimidine <sup>1</sup> H-NMR [CDCl <sub>3</sub> , δ 8.93 (d, J = 5 Hz, 2H), 8.38 (d, J = 9 Hz, 1H), 7.55 (t, J = 5 Hz, 1H), 7.06 (d, J = 9 Hz, 1H), 3.87 (s, 3H)]	
6		<b>MS</b> [m/z (M+H) <sup>+</sup> =(Calculated for C <sub>9</sub> H <sub>8</sub> N <sub>4</sub> O <sub>5</sub> S+H: 285.03) found: 385.1]
	2-((1H-imidazol-2-yl)sulfonyl)-6-methoxy-3-nitropyridine <sup>1</sup> H-NMR [DMSO-d <sub>6</sub> , δ 14.09 (s, 1H), 8.54 (d, J = 9 Hz, 1H), 7.63-7.28 (m, 3H), 3.55 (s, 3H)]	
7		<b>MS</b> [m/z (M+H) <sup>+</sup> =(Calculated for C <sub>10</sub> H <sub>9</sub> N <sub>3</sub> O <sub>5</sub> S <sub>2</sub> +H: 316.01) found: 315.8]
	2-((6-methoxy-3-nitropyridin-2-yl)sulfonyl)-4-methylthiazole <sup>1</sup> H-NMR [CDCl <sub>3</sub> , δ 8.30 (d, J = 9 Hz, 1H), 7.41 (s, 1H), 6.98 (d, J = 9 Hz, 1H), 3.60 (s, 3H), 2.55 (s, 3H)]	

5

#### Example 8: 6-Methoxy-3-nitro-2-(pyridin-2-ylsulfinyl)-pyridine



(a) 6-Methoxy-3-nitro-2-(pyridin-2-ylsulfanyl)-pyridine



5

To a solution of 6-methoxy-2-chloro-3-nitro pyridine (5 g, 26.59 mmol) in dimethylformamide (50 mL) was added potassium carbonate (4.40 g, 31.91 mmol) and 2-mercaptop pyridine (3.62 g, 29.25 mmol) at room temperature. The reaction mixture was stirred overnight at room temperature. Progress of reaction was monitored by LCMS. The reaction mixture was quenched with ice cold water (10 mL) and was extracted with ethyl acetate (100 mL). The organic layer was washed with water (3 x 20 mL) followed by brine (1 x 30 mL). The organic layer was dried over anhydrous sodium sulphate and was evaporated under reduced pressure to give the crude product which was purified by column chromatography eluting with 5% ethyl acetate in hexane affording the sub-title compound as yellow solid (3 g, 42.85%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 8.72 (d, J= 3.4 Hz, 1H), 8.39 (d, J= 8.9 Hz, 1H), 7.79-7.75 (m, 1H), 7.68 (d, J= 7.7 Hz, 1H), 7.35-7.33 (m, 1H), 6.49 (d, J= 9.0 Hz, 1H), 3.32 (s, 3H); LCMS [m/z (M+H)<sup>+</sup>]264 (MW calc = 263), R<sub>t</sub> = 1.83

20

(b) 6-methoxy-3-nitro-2-(pyridin-2-ylsulfinyl)-pyridine

To a solution of 6-methoxy-3-nitro-2-(pyridin-2-ylsulfanyl)-pyridine (1.5 g, 57.03 mmol) in dichloromethane (30 mL) was added m-chloroperbenzoic acid (1.47 g, 85.55 mmol) at room temperature. The reaction mixture was stirred at room temperature overnight. Progress of reaction was monitored by LCMS. The reaction mixture was diluted with dichloromethane (20 mL) and washed with saturated sodium sulphite solution (2 x 20 mL) followed by brine (1 x 20 mL). The organic layer was dried over anhydrous sodium sulphate and was evaporated under reduced pressure to give the crude product which was

purified by column chromatography eluting with 20% ethyl acetate in hexane affording the title compound as yellow solid (1.59 g, 37.67%).

<sup>1</sup>H NMR (DMSO-d<sub>6</sub>, 400 MHz) δ 8.59-8.51 (m, 2H), 8.06 (d, J= 7.5 Hz, 1H), 7.97 (d, J= 7.7 Hz, 1H), 7.52 (d, J= 6.0 Hz, 1H), 7.18 (d, J= 8.9 Hz, 1H), 3.97 (s, 3H);

5 LCMS [m/z (M+H)<sup>+</sup>] 280 (MW calc = 279); R<sub>t</sub> = 1.56;

HPLC purity at λ=210nm: 99.05%.

### Biological Examples

#### 10 Biological Example 1: Inhibition of recombinant TrxR1 and GR

Small molecule inhibition of recombinant thioredoxin reductase 1 (TrxR1) and glutathione reductase (GR) was examined in 96-well plate format. 30nM TrxR1 was incubated in the presence of 250μM NADPH, 0.1mg/ml BSA, and various concentrations of the compounds

15 (1% DMSO final) in 50mM Tris (pH 7.5) and 2mM EDTA buffer for 15 minutes. Following the incubation period, 2mM DTNB was added to each well and the change in O.D. at 412nm was followed. Percent activity was determined using DMSO vehicle and no TrxR1 (blank) controls. 2nM GR was incubated in the presence of 250μM NADPH, 0.1mg/ml BSA, and various concentrations of compounds (1% DMSO final) in 50mM Tris (pH 7.5) and 2mM EDTA buffer for 15 minutes. Following the incubation period, 1mM GSSG was added to each well and the change in O.D. at 340nm was followed. Percent activity was determined using DMSO vehicle and no GR (blank) controls.

20 Using the assays described in Biological Example 1, the following IC<sub>50</sub> values were

25 obtained. The results obtained are provided in Table 1 below.

Example	TrxR inhibition (nM)	GR inhibition (μM)
1	26.8	64.19
2	56.9	9.89
3	558	>100μM
4	0.854	11.17
5	10.8	>100μM
6	3.99	>100μM
7	6.90	>100μM
8	5.50	-

Biological Example 2: Head and neck cancer cell viability assay

FaDu cells were plated 2000 cells/well in 96-well black optical plates in the presence of 10% FBS media containing 25nM selenite. The following day cells were treated with 5 various concentrations of the compound of Example 1 (0.1% DMSO final) and incubated for 72hrs. After the incubation Cell-Quanti Blue reagent was added to each well and incubated for additional 3hrs. Fluorescence was read ex:530nm/em:590nm, and percent of viability was determined using DMSO vehicle and no cell (blank) controls.

10 Using the assays described in Biological Example 2, the following IC<sub>50</sub> values were obtained. The results obtained are provided in Table 2 below.

Example	FaDu Cell IC50 (μM)
1	1.61
2	0.61
3	2.89
7	45.71

Bioloical Example 3: Breast cancer cell viability assay

15 MDA-MB-231 cells were plated 2000 cells/well in 96-well black optical plates in the presence of 10% FBS media containing 25nM selenite. The following day cells were treated with various concentrations of compounds (0.1% DMSO final) and incubated for 72hrs. After the incubation Alamar Blue reagent was added to each well and incubated 20 for additional 3hrs. Fluorescence was read ex:530nm/em:590nm, and percent of viability was determined using DMSO vehicle and no cell (blank) controls.

Using the assays described in Biological Example 3, the following IC<sub>50</sub> values were obtained. The results obtained are provided in Table 3 below.

Example	MDA-MB-231 Cell viability IC50 (μM)
1	3.61
4	>100μM
5	4.54
6	10.85

7	3.09
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Biological Example 4: Cancer cell viability assay

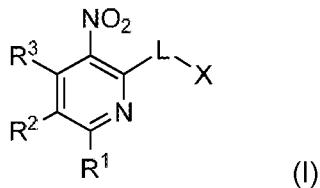
5 Breast cancer and glioblastoma cell lines were plated 4000 cells/well in 96-well plates in the presence of 10% FBS media. The following day cells were treated with various concentrations of example compounds (0.1% DMSO final) and incubated for 72hrs. After the incubation An MTT assay was performed to access cell viability. Percent of viability was determined using DMSO vehicle and no cell (blank) controls.

10 Using the assays described in Biological Example 4, the following IC<sub>50</sub> values were obtained. The results obtained are provided in Table 4 below.

Example	U-87 MG IC <sub>50</sub> ( $\mu$ M)	MDA-MB-231 IC <sub>50</sub> ( $\mu$ M)	MDA-MB-468 IC <sub>50</sub> ( $\mu$ M)
1	8.2	2.97	4.34
8	2.53	1.02	0.96

## Claims

1. A compound of formula I



or a pharmaceutically acceptable salt thereof, wherein:

L represents  $-S(O)_n^-$ ;

10

n represents 2 or 1;

X represents a heteroaryl group, attached to L via a carbon atom, optionally substituted by one or more groups independently selected from Y;

15

$R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo,  $R^{a1}$ ,  $-CN$ ,  $-A^{a1}-C(Q^{a1})R^{b1}$ ,  $-A^{b1}-C(Q^{b1})N(R^{c1})R^{d1}$ ,  $-A^{c1}-C(Q^{c1})OR^{e1}$ ,  $-A^{d1}-S(O)_pR^{f1}$ ,  $-A^{e1}-S(O)_pN(R^{g1})R^{h1}$ ,  $-A^{f1}-S(O)_pOR^{i1}$ ,  $-N_3$ ,  $-N(R^{j1})R^{k1}$ ,  $-N(H)CN$ ,  $-NO_2$ ,  $-ONO_2$ ,  $-OR^{l1}$  or  $-SR^{m1}$ ;

20

each  $A^{a1}$  to  $A^{f1}$  independently represents a single bond,  $-N(R^{p1})-$  or  $-O-$ ;

each  $Q^{a1}$  to  $Q^{c1}$  independently represents  $=O$ ,  $=S$ ,  $=NR^{n1}$  or  $=N(OR^{o1})$ ;

25

each  $R^{a1}$  and  $R^{f1}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{1a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{1b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{1c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{1d}$ ;

30

each  $R^{b1}$ ,  $R^{c1}$ ,  $R^{d1}$ ,  $R^{e1}$ ,  $R^{g1}$ ,  $R^{h1}$ ,  $R^{i1}$ ,  $R^{j1}$ ,  $R^{k1}$ ,  $R^{l1}$ ,  $R^{m1}$ ,  $R^{n1}$ ,  $R^{o1}$  and  $R^{p1}$  independently represents H,  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{1a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{1b}$ , aryl optionally substituted by one or more

groups independently selected from  $G^{1c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{1d}$ ;

any of  $R^{c1}$  and  $R^{d1}$ ,  $R^{g1}$  and  $R^{h1}$  and/or  $R^{j1}$  and  $R^{k1}$  are linked together to form, together with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from halo, and  $C_{1-3}$  alkyl,  $C_{2-3}$  alkenyl or  $C_{2-3}$  alkynyl each optionally substituted by one or more halo, and  $=O$ ;

10 each  $G^{1a}$  and  $G^{1b}$  independently represents halo,  $-CN$ ,  $-N(R^{a2})R^{b2}$ ,  $-OR^{c2}$ ,  $-SR^{d2}$  or  $=O$ ;

each  $G^{1c}$  and  $G^{1d}$  independently represents halo,  $-CN$ ,  $-N(R^{a2})R^{b2}$ ,  $-OR^{c2}$  or  $-SR^{d2}$ ;

each  $R^{a2}$ ,  $R^{b2}$ ,  $R^{c2}$  and  $R^{d2}$  independently represents H or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more fluoro; or

20  $R^{a2}$  and  $R^{b2}$  are linked together to form, along with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from fluoro,  $C_{1-3}$  alkyl,  $C_{2-3}$  alkenyl or  $C_{2-3}$  alkynyl each optionally substituted by one or more fluoro;

each  $Y$  independently represents halo,  $R^{a3}$ ,  $-CN$ ,  $-A^{a2}-C(Q^{a2})R^{b3}$ ,  $-A^{b2}-C(Q^{b2})N(R^{c3})R^{d3}$ ,  $-A^{c2}-C(Q^{c2})OR^{e3}$ ,  $-A^{d2}-S(O)_qR^{f3}$ ,  $-A^{e2}-S(O)_qN(R^{g3})R^{h3}$ ,  $25 -A^{f2}-S(O)_qOR^{i3}$ ,  $-N_3$ ,  $-N(R^{j3})R^{k3}$ ,  $-N(H)CN$ ,  $-NO_2$ ,  $-ONO_2$ ,  $-OR^{l3}$  or  $-SR^{m3}$ ;

each  $Q^{a2}$  to  $Q^{c2}$  independently represents  $=O$ ,  $=S$ ,  $=NR^{n3}$  or  $=N(OR^{o3})$ ;

each  $A^{a2}$  to  $A^{f2}$  independently represents a single bond,  $-N(R^{p3})-$  or  $-O-$ ;

30 each  $R^{a3}$  and  $R^{f3}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{2a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{2b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{2c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{2d}$ ;

each  $R^{b3}$ ,  $R^{c3}$ ,  $R^{d3}$ ,  $R^{e3}$ ,  $R^{g3}$ ,  $R^{h3}$ ,  $R^{i3}$ ,  $R^{j3}$ ,  $R^{k3}$ ,  $R^{l3}$ ,  $R^{m3}$ ,  $R^{n3}$ ,  $R^{o3}$  and  $R^{p3}$  independently represents H,  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{2a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{2b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{2c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{2d}$ ; or

any two  $R^{c3}$  and  $R^{d3}$ ,  $R^{g3}$  and  $R^{h3}$  and/or  $R^{i3}$  and  $R^{k3}$  are linked together to form, along with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring 10 optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from heterocyclyl optionally substituted by one or more groups independently selected from  $G^{2b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{2c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{2d}$ , and =O;

15 each  $G^{2a}$  independently represents halo, -CN, -N( $R^{j4}$ ) $R^{k4}$ , -OR<sup>l4</sup>, -SR<sup>m4</sup> or =O;

each  $G^{2b}$  independently represents halo,  $R^{a4}$ , -CN, -N( $R^{j4}$ ) $R^{k4}$ , -OR<sup>l4</sup>, -SR<sup>m4</sup> or =O;

20 each  $G^{2c}$  and  $G^{2d}$  independently represents halo,  $R^{a4}$ , -CN, -A<sup>a3</sup>-C( $Q^{a4}$ ) $R^{b4}$ , -A<sup>b3</sup>-C( $Q^{b3}$ )N( $R^{c4}$ ) $R^{d4}$ , -A<sup>c3</sup>-C( $Q^{c3}$ )OR<sup>e4</sup>, -A<sup>d3</sup>-S( $O$ )<sub>q</sub> $R^{f4}$ , -A<sup>e3</sup>-S( $O$ )<sub>q</sub>N( $R^{g4}$ ) $R^{h4}$ , -A<sup>f3</sup>-S( $O$ )<sub>q</sub>OR<sup>i4</sup>, -N<sub>3</sub>, -N( $R^{j4}$ ) $R^{k4}$ , -N(H)CN, -NO<sub>2</sub>, -ONO<sub>2</sub>, -OR<sup>l4</sup> or -SR<sup>m4</sup>;

each  $Q^{a3}$  to  $Q^{c3}$  independently represents =O, =S, =NR<sup>n4</sup> or =N(OR<sup>o4</sup>);

25 each A<sup>a3</sup> to A<sup>f3</sup> independently represents a single bond, -N( $R^{p4}$ )- or -O-;

each  $R^{a4}$  and  $R^{f4}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each 30 optionally substituted by one or more groups independently selected from  $G^{3a}$ , heterocyclyl optionally substituted by one or more groups independently selected from  $G^{3b}$ , aryl optionally substituted by one or more groups independently selected from  $G^{3c}$ , or heteroaryl optionally substituted by one or more groups independently selected from  $G^{3d}$ ;

35 each  $R^{b4}$ ,  $R^{c4}$ ,  $R^{d4}$ ,  $R^{e4}$ ,  $R^{g4}$ ,  $R^{h4}$ ,  $R^{i4}$ ,  $R^{j4}$ ,  $R^{k4}$ ,  $R^{l4}$ ,  $R^{m4}$ ,  $R^{n4}$ ,  $R^{o4}$  and  $R^{p4}$  independently represents H,  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more groups independently selected from  $G^{3a}$  or heterocyclyl optionally substituted by one or more groups independently selected from  $G^{3b}$ , aryl optionally substituted by one or more

groups independently selected from G<sup>3c</sup>, or heteroaryl optionally substituted by one or more groups independently selected from G<sup>3d</sup>; or

any of R<sup>c4</sup> and R<sup>d4</sup>, R<sup>g4</sup> and R<sup>h4</sup> and/or R<sup>j4</sup> and R<sup>k4</sup> are linked together to form, together with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected G<sup>3b</sup>;

each G<sup>3a</sup> and G<sup>3b</sup> independently represents halo, R<sup>a5</sup>, -CN, -N(R<sup>b5</sup>)R<sup>c5</sup>, -OR<sup>d5</sup>, -SR<sup>e5</sup> or =O;

each R<sup>a5</sup> independently represents C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl each optionally substituted by one or more groups independently selected from G<sup>4</sup>;

each R<sup>b5</sup>, R<sup>c5</sup>, R<sup>d5</sup> and R<sup>e5</sup> independently represents H, or C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl each optionally substituted by one or more groups independently selected from G<sup>4</sup>;  
or

each R<sup>b5</sup> and R<sup>c5</sup> are linked together to form, together with the nitrogen atom to which they are attached, a 3- to 6-membered ring, which ring optionally contains one further heteroatom and which ring optionally is substituted by one or more groups independently selected from G<sup>4</sup>;

each G<sup>4</sup> independently represents halo, R<sup>a6</sup>, -CN, -N(R<sup>b6</sup>)R<sup>c6</sup>, -OR<sup>d6</sup> or =O;

each R<sup>a6</sup> independently represents C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl each optionally substituted by one or more fluoro;

each R<sup>b6</sup>, R<sup>c6</sup> and R<sup>d6</sup> independently represents H, or C<sub>1-6</sub> alkyl, C<sub>2-6</sub> alkenyl or C<sub>2-6</sub> alkynyl each optionally substituted by one or more fluoro; and

each p and q independently represents 1 or 2,

with the provisos that the compound of formula I does not represent:

(A)

3-nitro-2-(pyridin-2-ylsulfonyl)pyridine,  
2-((3-nitropyridin-2-yl)sulfonyl)pyrimidine, or

*N*-(6-chloro-2-((5-chloro-3-nitropyridin-2-yl)sulfonyl)pyridin-3-yl)acetamide;

or

5 (B)  
3-nitro-2-[(3-nitro-2-thienyl)sulfinyl]-pyridine.

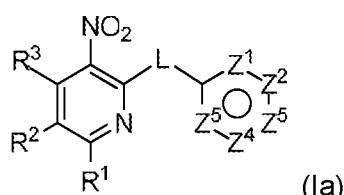
2. A compound as claimed in Claim 1, wherein X is unsubstituted or substituted with one or two Y groups.

10 3. A compound as claimed in Claim 1 or Claim 2, wherein each Y independently represents halo,  $R^{a3}$ ,  $-N(R^{j3})R^{k3}$  or  $-OR^{l3}$ .

4. A compound as claimed in any one of Claims 1 to 3, wherein:  
15 each  $R^{a3}$  independently represents  $C_{1-6}$  alkyl optionally substituted by one or more fluoro; and/or each  $R^{j3}$ ,  $R^{k3}$  and  $R^{l3}$  independently represents H or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more fluoro.

20 5. A compound as claimed in any one of Claims 1 to 4, wherein:  
X is unsubstituted or substituted with one Y; and/or  
Y represents halo or  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more fluoro.

25 6. A compound as claimed in any one of Claims 1 to 5, wherein the compound of formula I is a compound of formula Ia



wherein:

30 L,  $R^1$ ,  $R^2$  and  $R^3$  and are defined in any one of Claims 1 to 5;

each of  $Z^1$  to  $Z^5$  represents  $CR^4$  to  $CR^8$ , respectively, with the exception that one or two of  $Z^1$  to  $Z^5$  instead represents a heteroatom, which where possible may be substituted with  $R^9$ , and optionally one of  $Z^1$  to  $Z^5$  may instead represent a direct bond; and

5 each of  $R^4$  to  $R^9$  represents H or Y as defined in any one of Claims 1 to 5.

7. A compound as claimed in any one of Claim 6, wherein each of  $R^4$ ,  $R^5$ ,  $R^7$ ,  $R^8$  and  $R^9$  (where present) represents H and  $R^6$  (where present) represents H or Y, wherein Y represents methyl optionally substituted by one or more fluoro.

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8. A compound as claimed in any one of Claims 1 to 7, wherein  $R^1$ ,  $R^2$  and  $R^3$  each independently represents H, halo,  $R^{a1}$ ,  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$ .

9. A compound as claimed in any one of Claims 1 to 8, wherein:

15  $R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo,  $R^{a1}$ ,  $-N(R^{j1})R^{k1}$ ,  $-OR^{l1}$  or  $-SR^{m1}$ ; and/or each of  $R^{a1}$ ,  $R^{j1}$ ,  $R^{k1}$ ,  $R^{l1}$  and  $R^{m1}$  independently represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more fluoro.

10. A compound as claimed in any one of Claims 1 to 9, wherein  $R^1$ ,  $R^2$  and  $R^3$  each independently represent H, halo,  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$

20 11. A compound as claimed in any one of Claims 1 to 10, wherein:

$R^2$  and  $R^3$  each represent H;

$R^1$  represents H, halo,  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$ ; and

25 each  $R^{j1}$ ,  $R^{k1}$  and  $R^{l1}$  represents  $C_{1-6}$  alkyl,  $C_{2-6}$  alkenyl or  $C_{2-6}$  alkynyl each optionally substituted by one or more fluoro.

12. A compound as claimed in any one of Claims 1 to 10, wherein:

$R^2$  and  $R^3$  each represent H;

30  $R^1$  represents halo,  $-N(R^{j1})R^{k1}$  or  $-OR^{l1}$ ; and

each  $R^{j1}$ ,  $R^{k1}$  and  $R^{l1}$  represents methyl optionally substituted by one or more fluoro.

13. A compound as defined in any one of Claims 1 to 12 but without the provisos for use as a pharmaceutical.

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14. A compound as defined in any one of Claims 1 to 12 but without the provisos for use in the treatment of cancer.

15. The use of a compound as defined in any one of Claims 1 to 12 but without the provisos for the manufacture of a medicament for the treatment of cancer.

5 16. A method of treating cancer comprising administering to a patient in need thereof a therapeutically effective amount of a compound as defined in any one of Claims 1 to 12 but without the provisos.

17. The compound for use, use or method of Claims 14 to 16, wherein the cancer is

10 selected from the group consisting of:

soft tissue cancers, such as sarcoma, myxoma, rhabdomyoma, fibroma, lipoma and teratoma;

lung cancers, such as bronchogenic carcinoma, alveolar or bronchiolar carcinoma, bronchial adenoma, sarcoma, lymphoma, chondromatous hamartoma, mesothelioma;

15 gastrointestinal cancers: such as esophageal cancers, stomach cancers, pancreatic cancers, small bowel cancers, large bowel cancers;

genitourinary tract cancers, such as cancer of the kidney, bladder and urethra, prostate, testis;

liver cancers, such as hepatoma, cholangiocarcinoma, hepatoblastoma, angiosarcoma, 20 hepatocellular adenoma, hemangioma;

bone cancers, such as osteogenic sarcoma, fibrosarcoma, malignant fibrous histiocytoma, chondrosarcoma, Ewing's sarcoma, malignant lymphoma, multiple myeloma, malignant giant cell tumor chordoma, osteochronfroma, benign chondroma, chondroblastoma, chondromyxofibroma, osteoid osteoma and giant cell tumors;

25 cancers of the head and/or nervous system, such as cancer of the skull, meninges, brain, spinal cord;

gynecological cancers, such as cancers of the uterus, cervix, ovaries, cancers of the vulva, vagina, fallopian tubes;

30 haematologic cancers, such as cancers of the blood and bone marrow, Hodgkin's disease, non-Hodgkin's lymphoma;

skin cancers, such as malignant melanoma, basal cell carcinoma, squamous cell carcinoma, Kaposi's sarcoma, moles dysplastic nevi, lipoma, angioma, dermatofibroma, keloids; neurofibromatosis and adrenal glands; and neuroblastomas.

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18. The compound for use, use or method of Claims 14 to 17, wherein the cancer is a solid tumor cancer.

19. A pharmaceutical composition comprising a compound as defined in any one of Claims 1 to 12 but without the provisos, and optionally one or more pharmaceutically acceptable adjuvant, diluent and/or carrier.

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20. A combination product comprising:

(A) a compound as defined in any one of Claims 1 to 12, but without the provisos; and

(B) one or more other therapeutic agent that is useful in the treatment of cancer,

wherein each of components (A) and (B) is formulated in admixture, optionally with one or

10 more a pharmaceutically-acceptable adjuvant, diluent or carrier.

21. A kit-of-parts comprising:

(a) a pharmaceutical formulation as defined in Claim 19; and

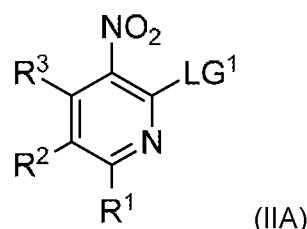
(b) one or more other therapeutic agent that is useful in the treatment of cancer,

15 optionally in admixture with one or more pharmaceutically-acceptable adjuvant, diluent or carrier,

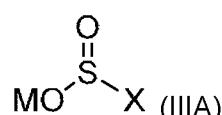
which components (a) and (b) are each provided in a form that is suitable for administration in conjunction with the other.

20 22. A process for the preparation of a compound as defined in any one of Claims 1 to 12, including the provisos, which process comprises:

(i) where n represents 2, reaction of a compound of formula IIA

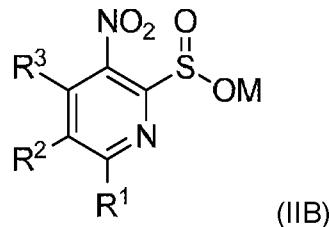


wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are as defined in any one of Claims 1 to 12 and LG<sup>1</sup> represents a suitable leaving group, with a compound of formula IIIA

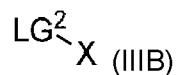


wherein X is as defined in any one of Claims 1 to 12 and M represents an alkali metal ion, in the presence of a suitable acid and in the presence of a suitable solvent, and optionally in the presence of a suitable phase transfer catalyst;

5 (ii) where n represents 2, reaction of a compound of formula IIB



10 wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are as defined in any one of Claims 1 to 12 and M represents an alkali metal ion, with a compound of formula IIIB



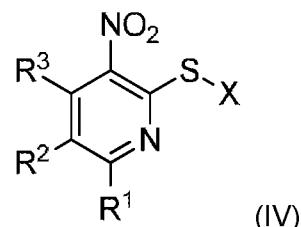
15 wherein X is as defined in any one of Claims 1 to 12 and LG<sup>2</sup> represents a suitable leaving group, in the presence of a suitable acid and in the presence of a suitable solvent, and optionally in the presence of a suitable phase transfer catalyst;

20 (iii) where n represents 2, reaction of a compound of formula IIA with a compound of formula IIIA, in the presence of a suitable metal halide and in the presence of a suitable solvent;

(iv) where n represents 2, reaction of a compound of formula IIB with a compound of formula IIIB, in the presence of a suitable metal halide and in the presence of a suitable solvent;

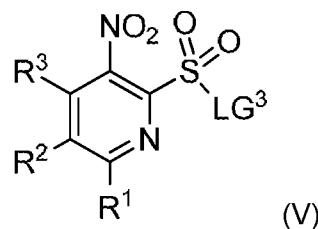
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(v) reaction of a compound of formula IV

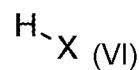


wherein R<sup>1</sup> to R<sup>3</sup> and X are as defined in any one of Claims 1 to 12, with a suitable oxidising agent in the presence of a suitable solvent, and optionally in the presence of water;

5 (vi) where n represents 2, reaction of a compound of formula V



10 wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> are as defined in any one of Claims 1 to 12 and LG<sup>3</sup> represents a suitable leaving group with a compound of formula VI

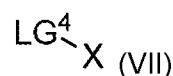


15 wherein X is as defined in any one of Claims 1 to 12, in the presence of a suitable Lewis acid and in the presence of a suitable solvent;

(vii) where n represents 2, reaction of a compound of formula V with a compound of formula VI, in the presence of a suitable catalyst and a suitable base, and in the presence of a suitable solvent;

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(viii) where n represents 2, reaction of a compound of formula V with a compound of formula VII



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wherein X is as defined in any one of Claims 1 to 12 and LG<sup>4</sup> represents a suitable leaving group, in the presence of a suitable catalyst and in the presence of a suitable solvent; or

(ix) where n represents 2, reaction of a compound of formula IIB with (a) a compound of formula VI having at least one Y group, or (b) a compound of formula VI having a group that may be converted to a Y group, wherein the Y group or group that may be converted to a Y group is present in the alpha position relative to the essential H substituent and

represents a suitable directing group, in the presence of a suitable catalyst and/or oxidant, and in the presence of a suitable solvent, which step may further comprise conversion of the group that may be converted to a Y group to the required Y group.

5 23. A compound, compound for use, use, method, formulation, formulation for use or process substantially as described herein, with reference to the examples.

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/GB2018/050343

**A. CLASSIFICATION OF SUBJECT MATTER**  
 INV. C07D403/12 C07D401/12 C07D417/12 A61K31/427 A61K31/44  
 A61P35/00

**ADD.**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
C07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, CHEM ABS Data, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 031 173 A1 (DUPHAR INT RES [NL]) 1 July 1981 (1981-07-01) claims; page 4, compound 30 -----	1
A	TAKAHASHI, TORIZO; MAKI, YOSHIFUMI: "Sulfur-containing Pyridine Derivatives. LVI. Smiles Rearrangement of Pyridine Derivatives and Synthesis of Benzopyrido-and Dipyrido-1, 4-thiazine Derivatives. (4).", CHEMICAL & PHARMACEUTICAL BULLETIN, vol. 6, no. 4, 21 February 1958 (1958-02-21), pages 369-373, XP002780592, DOI: 10.1248/cpb.6.369 page 369, compounds (V), (XIII), (XVI) ----- -/-	1



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 May 2018	28/05/2018

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**INTERNATIONAL SEARCH REPORT**

International application No PCT/GB2018/050343
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## C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/138820 A2 (HARVARD COLLEGE [US]; AKTAS HUSEYIN [US]; HALPERIN JOSE A [US]; CHOREV) 2 December 2010 (2010-12-02) claims; examples -----	1
2		

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2018/050343

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