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JOSE LLOREDA CAMACHO & CO.

Calle 72 No. 5-83 Piso 5, Bogotá, D.C. Tel: 6069700 Fax 6069701

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO



No: 04-122509- -00009-0000

Fecha: 2008-06-11 16:55:17 Dep. 2020 NUECREACIONE
Tra. 11 PATENTEIYII Eve: 379 FASENACIONALII
Act. 467 SOLICIPRORROGA Folios: 2

Señor

SUPERINTENDENTE DE INDUSTRIA Y COMERCIO

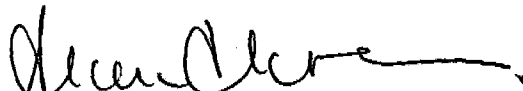
DIVISION DE NUEVAS CREACIONES

E. S. D.

Re: P1.-WYETH.-Solicitud de Patente de Invención en Fase
Nacional PCT para "NUEVA SAL FORMIATO DE O-
DESMETILVENLAFAXINA".-Clase A61K 31/19.-Expediente
número 04-122.509.-

1. Me refiero al auto dictado por ese Despacho notificado por fijación en lista de 14 de Marzo de 2008.
2. Atentamente ruego a usted concederme un plazo de treinta (30) días para dar respuesta al auto antes mencionado, cuyo término vence el **16 de Junio de 2008.**
3. Anexo acompaño recibo número 08-46,684, que acredita el pago de los derechos que dicho plazo causa.
4. Ruego a usted tomar atenta nota de lo anterior y proceder de conformidad.

Señor Superintendente,


ALICIA LLOREDA RICAURTE
T.P. 53.215

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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO



No. 04-122509- -00009-0000

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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT : 800176089-2

OFICIAL DE CAJA : 08 - 46,684
: JUNIO 11 DE 2008

***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	No. PAGO	FECHA PGO	Vr. PAGO
LLOREDA Y CIA S. A	CONSIGNACION	BANCO DE BOGOTA	062754387	2756085	11/06/2008	1,366,000.00

***** CONCEPTO *****

RENTISTICO	CONCEPTO	TOTAL CONCEPTO
1 50005-01-08 PRORROGA DE TERMINOS	31 PRORROGA DE TERMINOS	75,000.00
TOTAL :		\$ 75,000.00

SON SETENTA Y CINCO MIL PESOS

RESPONSABLE :

RECIBO DE CAJA APLICADO AL EXPEDIENTE No.

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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO



No. 04-122509- -00010-0000

Fecha: 2008-07-28 16:39:20 Dep. 2020 NUECREACIONE
Tra. 11 PATENTE IYI Eve: 379 FASE NACIONAL II
Act. 444 RESPUESTA REQUE Folios: 61

Señor

SUPERINTENDENTE DE INDUSTRIA Y COMERCIO
DIVISION DE NUEVAS CREACIONES

E. S. D.

Re: P1.-WYETH-Solicitud de Patente de Invención en Fase Nacional PCT
para "NUEVA SAL FORMIATO DE O-DESMETILVENLAFAXINA".-Clase
A61K 31/19.-Expediente número 04-122.509.-

1. Me refiero al auto dictado por ese Despacho notificado por fijación en lista el 14 de Marzo de 2008, así como a mi solicitud de plazo del 11 de Junio de 2008 para dar respuesta al auto antes mencionado.

2. Con el fin de responder a las objeciones expuestas por el señor Examinador en su Concepto Técnico No. 417 bajo los acápites de claridad de la solicitud y nivel inventivo, atentamente me permito presentar los siguientes argumentos técnicos y las siguientes modificaciones hechas a la solicitud en cuestión, mediante lo cual no sólo se superan dichas objeciones, sino que además se demuestra en forma contundente la patentabilidad de la presente invención.

3. **MODIFICACIONES A LA SOLICITUD**

Inicialmente me permito manifestar ante ese Despacho que el solicitante de la invención en cuestión ha decidido alterar el capítulo reivindicatorio actualmente presentado, eliminando la reivindicación 41, modificando las reivindicaciones 40 y 42 a 47, y finalmente re-enumerando adecuadamente el nuevo capítulo reivindicatorio, el cual está compuesto por 46 reivindicaciones.

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En conexión con lo anterior, resulta de gran importancia resaltar que la modificación realizada en la reivindicación 40 consiste básicamente en la inclusión de la materia revelada en la reivindicación 41 actualmente presentada, razón por la cual dicha última reivindicación ha sido eliminada. Adicionalmente, todas las reivindicaciones 40 y 42 a 47 fueron modificadas mediante la inclusión de la expresión: *"Un compuesto el cual es"*, al inicio de cada una de dichas reivindicaciones.

De conformidad con lo anterior, es claro que dichas modificaciones no amplían de manera alguna el objeto inicial de la presente solicitud, tal como fue originalmente presentada.

4. CLARIDAD DE LA SOLICITUD

El señor Examinador ha objetado la claridad del capítulo reivindicatorio de la presente solicitud de patente con base en los siguientes argumentos:

- ***"Se observa continua caracterización de un compuesto en el capítulo reivindicatorio por características fisicoquímicas del mismo."***

En respuesta a lo anterior, inicialmente me permito destacar que **la reivindicación 1 de la presente solicitud está dirigida a proteger un compuesto químico específico**, esto es, el formiato de O-desmetilvenlafaxina, mientras que **las reivindicaciones 2 a 8, DEPENDIENTES DE LA REIVINDICACIÓN 1, establecen características técnicas adicionales de dicho compuesto específico.**

Como puede notarse, mediante dichas reivindicaciones el solicitante de la invención en cuestión no busca seleccionar el compuesto químico a proteger a partir de las características fisicoquímicas que éste deba presentar, toda vez que en la reivindicación 1 se está definiendo de manera clara que el compuesto a proteger es el formiato de O-desmetilvenlafaxina; por lo tanto, también es claro que **las características técnicas definidas en las reivindicaciones 2 a 8 corresponden únicamente a ese compuesto.**

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En vista de lo anterior, considero que las reivindicaciones 1 a 8 de la presente solicitud de patente son absolutamente claras y concisas. Es decir, cumplen a cabalidad con los requisitos de patentabilidad establecidos en el Artículo 30 de la Decisión 486 de 2000.

- ***"Reivindicaciones 21-24: Se reivindica una forma de dosificación farmacéutica por su composición, por su función final o por su presentación final mas no por las características esenciales de la forma de dosificación que se pretende proteger por lo cual no se acepta."***

En respuesta a la anterior objeción, en primer lugar considero que resulta de gran importancia resaltar que en el campo de la química farmacéutica y de la propiedad intelectual es comúnmente conocido que una forma de dosificación se refiere a la disposición externa que se le da a una formulación, la cual puede estar comprendida por una o más sustancias escogidas entre compuestos activos, excipientes y aditivos que facilitan su administración.

Ahora bien, de la atenta lectura de las reivindicaciones 21 y 24 de la presente solicitud de patente es claro que dichas reivindicaciones están dirigidas a proteger una forma de dosificación caracterizada porque comprende: 1) una cantidad terapéuticamente efectiva del compuesto formiato de O-desmetilvenlafaxina, 2) un transportador o excipiente farmacéuticamente aceptable (reivindicación 21), y porque dicha forma farmacéutica es una tableta ó una cápsula (reivindicación 24).

De lo anterior es claro que **dichas reivindicaciones revelan información técnica relevante para caracterizar una forma de dosificación, de manera que una persona medianamente versada en la materia técnica en cuestión encuentra en dichas reivindicaciones la información técnica necesaria para comprender a cabalidad las características de la materia que se desea proteger.**

De otro lado, atentamente me permito hacer notar al señor Examinador que las reivindicaciones 22 y 23 no están dirigidas a proteger "la función final" de la forma de dosificación definida en la reivindicación 21. En este sentido, resulta de gran importancia resaltar que el hecho de que una

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forma de dosificación sea de liberación prolongada (reivindicación 22) o de liberación controlada (reivindicación 23), no significa que esa acción sea la función o utilidad de dicha forma de dosificación; contrario a eso, **tales mecanismos de liberación representan indiscutiblemente una característica técnica propia de las formas de dosificación reivindicadas.**

En vista de lo planteado previamente, es claro que la materia revelada en las reivindicaciones 21 a 24 se encuentra definida de una manera clara y concisa, de manera que cumple a cabalidad con los requisitos establecidos en el Artículo 30 de la Decisión 486 de 2000.

- ***"Reivindicaciones 40-47: Se reivindica un compuesto llamado formiato de O-desmetilvenlafaxina no por sus características esenciales sino por el método por el cual se produce o por su relación de aspectos o por una propiedad física lo cual no puede aceptarse."***

En respuesta a lo anterior, me permito resaltar una vez más ante ese Despacho que en la presente solicitud de patente se revela un compuesto químico específico, esto es, el formiato de O-desmetilvenlafaxina. En este sentido, es claro que dicho compuesto está caracterizado inherentemente por una estructura química definida, la cual aparece, por ejemplo, en la página 3 de la descripción, y representa sin lugar a dudas la "característica esencial" de dicho novedoso compuesto.

De conformidad con lo anterior, resulta de gran importancia resaltar que **las reivindicaciones 40 a 46 definen la materia que se desea proteger no solamente por su característica esencial (toda vez que en cada una de ellas se define claramente que el compuesto a proteger es el formiato de O-desmetilvenlafaxina), sino también por otro tipo de características estructurales, como lo es, por ejemplo, su relación de aspectos.**

Por lo tanto, atentamente me permito manifestar que las reivindicaciones 40 a 46 de la presente solicitud de patente son claras, esto es, pueden ser comprendidas fácilmente por una persona capacitada en la materia técnica en cuestión. En consecuencia, dichas reivindicaciones cumplen a cabalidad con los requisitos de patentabilidad estipulados en el Artículo 30 de la Decisión 486 de 2000.

5. EVALUACIÓN DEL NIVEL INVENTIVO

De otro lado, el señor Examinador ha objetado el nivel inventivo de la materia revelada en la solicitud de patente en cuestión basándose en las enseñanzas de los siguientes documentos:

- US 4,535,186 (D1)
- "Nonaqueous capillary electrophoresis-mass spectrometry for separation of venlafaxine and its phase I metabolites" (D2)

En este sentido, el señor Examinador afirma que la única diferencia de la solicitud en estudio con D1 es que en dicha anterioridad no se menciona explícitamente la sal formiato de O-desmetilvenlafaxina, pero sin embargo allí sí se encuentran incluidas todas las sales farmacéuticamente aceptables para el principio activo venlafaxina, por lo cual la presente invención no está proporcionando un salto tecnológico sorprendente. Adicionalmente, el señor Examinador afirma que un experto en la materia esperaría que formando la sal formiato del compuesto debería mejorarse su solubilidad y absorción in vivo.

Finalmente, el señor Examinador concluye que:

"el compuesto y las variantes de composiciones en su forma de sal, así como su proceso de obtención, se consideran tan solo una alternativa o formas de presentación equivalentes al compuesto en su forma de base libre ya conocida con anterioridad por lo cual no se observa algún salto tecnológico que la haga superior o diferente a lo previamente conocido.

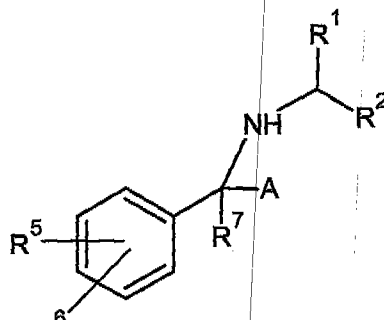
Así las cosas el Problema Técnico objetivo fundamental de la Invención reivindicada no puede definirse y el compuesto, procesos y composiciones reivindicados se consideran tan solo una alternativa, sin algún efecto que lo haga superior a lo previamente conocido.

Por consiguiente, de acuerdo a las consideraciones expuestas anteriormente, resultaría obvio para un experto en la materia llegar a desarrollar este tipo de compuesto en forma de sal a partir del principio activo en su forma de base libre ya existente previamente en el estado de la técnica, así como formular composiciones a partir de estos compuestos y desarrollar los procedimientos por medio de una reacción con un ácido."

Ahora bien, en vista de lo anterior y con el fin de responder adecuadamente a las objeciones de nivel inventivo realizadas por el señor Examinador en su Concepto Técnico, a continuación me permito analizar las enseñanzas de los documentos D1 y D2, y mostrar además una serie de argumentos técnicos que permiten superar completamente dichas objeciones.

5.1) Consideraciones Respecto al Documento US 4535186 (D1)

En términos generales, el documento D1 revela compuestos derivados de fenetilamina que son útiles como antidepresivos y presentan la siguiente estructura química general:



en donde los posibles significados de las variables A, R¹, R², R⁵, R⁶ y R⁷ están adecuadamente definidos, por ejemplo, en la columna 1 de dicho documento.

Adicionalmente, los autores de D1 establecen que las sales de adición ácida farmacéuticamente aceptables de los compuestos allí revelados son obtenidos convencionalmente mediante la reacción de la base libre con una cantidad equivalente de algún ácido que pueda formar una sal no tóxica. En este sentido, en D1 se establece que los posibles ácidos que pueden emplearse para tal fin son los ácidos clorhídrico, bromhídrico, fumárico, maleico, succínico, sulfúrico, fosfórico, tartárico, acético, cítrico, oxálico y ácidos similares.

Finalmente, en D1 también se enseñan algunos mecanismos de síntesis para obtener los compuestos químicos allí revelados.

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Ahora bien, con base en lo anterior y con el ánimo de demostrar el inequívoco carácter inventivo de la materia revelada en la presente solicitud de patente frente a las enseñanzas de dicho documento D1, a continuación me permito presentar ante ese Despacho las siguientes consideraciones técnicas:

- Inicialmente resulta de gran importancia resaltar que, tal como lo reconoce el señor Examinador en su Concepto Técnico, el documento D1 no enseña la sal formiato de O-desmetilvenlafaxina, es decir, no enseña el novedoso compuesto químico revelado en la presente solicitud de patente. A este respecto, me permito aclarar que en D1 únicamente se revela de manera explícita la sal fumarato de la O-desmetilvenlafaxina (ejemplo 26), compuesto químico que no solamente se caracteriza por presentar claras diferencias estructurales frente a la sal formiato, sino que adicionalmente presenta características fisicoquímicas y de permeabilidad que no son apropiadas para su uso farmacológico (lo anterior será analizado en detalle más adelante).

En consecuencia, es claro que la materia revelada en la solicitud de patente en cuestión presenta un inequívoco carácter novedoso frente a las enseñanzas del documento D1.

- De otro lado, en relación con la importancia y la obviedad de las sales farmacéuticamente aceptables de compuestos activos, atentamente me permito señalar ante ese Despacho que no existe ninguna razón técnica para aseverar que: "el experto en la materia esperaría que formando la sal formiato del compuesto se mejorara su solubilidad y absorción in vivo", y mucho menos para afirmar que: *"el compuesto y las variantes de composiciones en su forma de sal, así como su proceso de obtención, se consideran tan sólo una alternativa o formas de presentación equivalentes al compuesto en su forma de base libre ya conocida con anterioridad por lo cual no se observa algún salto tecnológico que lo haga superior o diferente a lo previamente conocido."*, tal como lo hace el señor Examinador en su Concepto Técnico.

En conexión con lo anterior, me permito poner en consideración de ese Despacho las enseñanzas de dos artículos científicos (adjuntos como anexo) relacionados con las sales farmacéuticas de compuestos activos:

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1. Berge S. M. et al., "Pharmaceutical salts", J. Pharm. Sci., 66 (1): 1-19, 5 (1977); y,
2. Bighley L. D. et al., "Salt forms fo drugs and absorption", Encyclopedia of Pharmaceutical Technology, Vol. 13, pp. 453-499 (1995).

En el primero de ellos, por ejemplo, claramente se establece lo siguiente:

"Las características químicas, biológicas, físicas y económicas de un agente medicinal pueden ser manipuladas, y por ende, optimizadas mediante la conversión a una forma de sal. Sin embargo, la selección de la sal apropiada puede ser una tarea muy difícil debido a que cada sal impone propiedades únicas al compuesto madre". (página 1 de Berge et al.)

Adicionalmente se establece que:

"Desafortunadamente, no existe un mecanismo para predecir la influencia de una especie de sal en particular sobre el comportamiento del compuesto madre", entre otras razones porque "varias sales de un mismo compuesto se comportan generalmente de manera muy diferente debido a las propiedades físicas, químicas y termodinámicas que imponen sobre dicho compuesto madre." (páginas 1 y 2 de Berge, et al.)

Asimismo, en el artículo escrito por Bighley y colaboradores se establece lo siguiente:

"...por lo tanto, la selección de una determinada sal aún se mantiene como ua decisión empírica y compleja, simplemente porque el hecho de que una forma de sal presente ciertas propiedades deseadas, no significa que otras formas de sal de la misma droga exhiban propiedades similares." (páginas 479 a 487 de Bighley et al.)

De lo anterior puede concluirse que las afirmaciones realizadas por el señor Examinador resultan ser completamente contrarias a lo enseñado en los artículos científicos de Berge et al. y Bighley et al., pese a que las conclusiones técnicas expuestas en dichos documentos son el resultado

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de una extensa revisión de las propiedades farmacéuticas mostradas por distintas sales de diferentes compuestos activos.

De conformidad con lo anterior, es claro como mientras en el artículo de Berge et al. se concluye que la selección de una sal puede influenciar significativamente las características químicas esenciales de una droga, como la solubilidad, la velocidad de disolución, la absorción, la toxicidad, la farmacocinética, la biodisponibilidad, la tensión superficial, la estabilidad, la tendencia a la desagregación y las propiedades organolépticas (páginas 4 a 16 de berge et al.), el señor Examinador afirma en su Concepto Técnico que: "no se considera que sales como el formiato de O-demetilvenlafaxina por mencionar alguna de las sales derivadas del principio activo venlafaxina tenga una diferencia tal con el propio compuesto u otra de sus sales o metabolitos mencionados por el estado de la técnica que le otorgue nivel invetivo a la solicitud en estudio debido a que un compuesto no se diferencia de otro tan sólo por sus propiedades fisicoquímicas tales como su solubilidad, endotermia, tamaño de partícula, etc, sino por las características químicas esenciales de la molécula como tal, a las cuales de se deben aquellas."

En este sentido, me permito manifestar ante ese Despacho que los artículos publicados por Berge et al. y Bighley et al. son una prueba contundente de que las formas de sal realmente proporcionan diferencias fisicoquímicas y farmacológicas significativas frente a un determinado compuesto activo madre.

- Finalmente, en este punto resulta de gran importancia resaltar una vez más ante ese Despacho que los resultados experimentales obtenidos por el solicitante de la invención en cuestión con la sal formiato de O-desmetilvenlafaxina (los cuales se encuentran adecuadamente detallados y analizados en las páginas 5 a 9 de la descripción) demuestran de manera contundente que dicha novedosa sal formiato presenta una mejor absorción en el intestino delgado y en el colon con respecto a lo observado con la sal fumarato (compuesto conocido en el estado de la técnica), hecho que puede favorecer ampliamente la biodisponibilidad, la farmacocinética y los perfiles de toxicidad de la sal formiato en comparación con las características farmacológicas mostradas por la sal fumarato.

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Por lo tanto, es claro que dichos resultados experimentales demuestran no solamente que la sal formiato de O-desmetilvenlafaxina es realmente un compuesto químico diferente a la base libre y a la sal fumarato, sino que también representa una sorprendente y significativa contribución técnica al estado del arte.

En conclusión, como resultado de todo lo expuesto previamente, me permito manifestar ante ese Despacho que la materia revelada en la solicitud de patente en cuestión presenta un inequívoco carácter novedoso e inventivo frente a las enseñanzas del documento D1.

5.2) Consideraciones Respecto al Documento "*Nonaqueous capillary electrophoresis -mass spectrometry for separation of venlafaxine and its phase I metabolites*" (D2)

En términos generales, el documento D2 revela métodos electroforéticos para separar el compuesto venlafaxina de sus metabolitos. Específicamente, dicha publicación enseña la utilidad de la electroforesis capilar no acuosa para lograr la efectiva separación de dichos compuestos químicos, revelando que si bien la separación completa es lograda a pH básico (valor cercano al pKa de la venlafaxina), bajo dichas condiciones no es posible obtener una resolución adecuada en los electroferogramas. Adicionalmente, en D2 se revela que al llevar a cabo la separación bajo condiciones ácidas no es posible lograr una separación completa de las drogas estudiadas. Finalmente, dicho documento enseña la realización de pruebas experimentales tendientes a estudiar el comportamiento del sistema bajo estudio en un medio no acuoso, esto es, utilizando diferentes mezclas metanol-acetonitrilo y empleando soluciones de formiato de amonio 25 mM y ácido fórmico 1 M.

Ahora bien, con base en lo planteado previamente, me permito manifestar que la materia revelada en la solicitud de patente en cuestión presenta un inequívoco carácter inventivo frente a las enseñanzas del documento D2, toda vez que:

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- En dicha anterioridad NO es mencionado y tampoco sugerido el compuesto formiato de O-desmetilvenlafaxina sólido;
- El documento D2 se encuentra dirigido exclusivamente a describir un medio electroforético para permitir la migración diferenciada de la venlafaxina y sus metabolitos, el cual eventualmente puede comprender ácido fórmico como parte de una solución buffer, es decir, como parte de la solución iónica necesaria para la realización de dichas pruebas electroforéticas; y,
- Una persona experta en la materia técnica en cuestión no encuentra en el documento D2 ningún tipo de indicación técnica que le pueda sugerir que el compuesto formiato de O-demetilvenlafaxina presenta las propiedades farmacológicas ventajosas reveladas en la presente solicitud de patente frente a la forma base ó a frente a la sal fumarato, de manera que dicha persona experta no cuenta con ninguna razón técnica para sugerir la utilidad de sintetizar dicho novedoso compuesto.

De conformidad con lo anterior, y tal como se ha analizado a lo largo del presente memorial, es absolutamente claro que la materia revelada en la presente solicitud de patente presenta un inobjetable carácter inventivo frente a las enseñanzas de los documentos D1 y D2, de manera que dicha solicitud cumple a cabalidad con los requisitos de patentabilidad establecidos en el Artículo 18 de la Decisión 486 de 2000.

6. **CONCLUSIÓN**

De conformidad con las modificaciones realizadas en el capítulo reivindicatorio de la solicitud de patente en cuestión, y como consecuencia de las consideraciones técnicas presentadas para demostrar el inequívoco carácter inventivo de la presente invención, dentro de las que se incluyen:

- 1) la imposibilidad de predecir las características fisicoquímicas y farmacológicas presentadas por una determinada sal de un compuesto activo;

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- 2) las propiedades técnicas sorprendentes y ventajosas presentadas por el novedoso compuesto formiato de O-desmetilvenlafaxina en comparación con la forma base y la sal fumarato (compuestos conocidos en el estado de la técnica); y
- 3) la inexistencia de sugerencias técnicas dentro de la materia revelada en los documentos D1 y D2 para que una persona experta en la materia pudiera predecir las sorprendentes ventajas técnicas reveladas en la solicitud de patente en cuestión,

Es absolutamente claro que se han superado satisfactoriamente las objeciones expuestas por el señor Examinador frente a la solicitud de patente en cuestión, y por tanto, dicha solicitud es merecedora del privilegio de patente solicitado.

7. Anexo al presente memorial me permito presentar:

- (a) Recibo número 08-57,491, expedido por la Superintendencia de Industria y Comercio, que acredita el pago de las modificaciones mencionadas;
- (b) Copia del nuevo Capítulo Reivindicatorio compuesto por 46 reivindicaciones, el cual reemplaza al actualmente presentado y en el que se han realizado las modificaciones previamente mencionadas; y
- (c) Copia de los artículos científicos:
 - Berge S. M. et al., "Pharmaceutical salts", J. Pharm. Sci., 66 (1): 1-19, 5 (1977); y
 - Bighley L. D. et al., "Salt forms fo drugs and absorption", Encyclopedia of Pharmaceutical Technology, Vol. 13, pp. 453-499 (1995).

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JOSE LLOREDA CAMACHO & CO.

Calle 72 No. 5-83 Piso 5, Bogotá, D.C. Tel: 6069700 Fax 6069701

8. En vista de todo lo anterior, ruego a usted proceder a estudiar nuevamente la solicitud a la luz de las argumentaciones presentadas y de las modificaciones realizadas y conceder el privilegio de patente solicitado.

Señor Superintendente,

Alicia Lloreda Ricaurte

ALICIA LLOREDA RICAURTE

T.P. 53.215

NOTARIA SEXTA DE BOGOTÁ

RECONOCIMIENTO Y PRESENTACION PERSONAL

Bogotá, D.C.

Ante mi PABLO MENDEZ BARAJAS

NOTARIO SEXTO (E) DEL CIRCULO DE BOGOTÁ

Comparecieron:

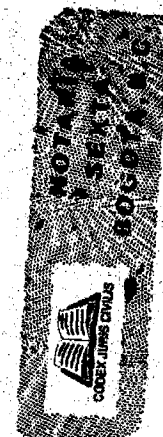
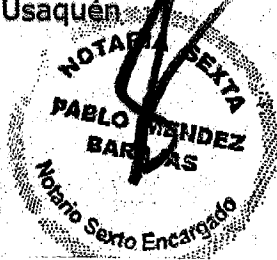
quien (es) exhibió(eron) la(s) C.C.

C.C. 39.690.713

y declaró(aron) que la(s) firma(s) que aparece(n) en el presente documento es(son) la(s) cuya(s) y que el contenido del mismo es cierto. En constancia se firma esta diligencia.

Alicia Lloreda Ricaurte
ALICIA LLOREDA RICAURTE

C.C. No. 39.690.713 de Usaquén



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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT : 800176089-2

RECIBO OFICIAL DE CAJA : 08 - 57.491
FECHA : JULIO 18 DE 2008

***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	No. PAGO	FECHA PAGO	Vr. PAGO
LOREDA Y CIA S. A	CONSIGNACION	BANCO DE BOGOTA	062754387	1859832	18/07/2008	6,734,000.00

***** CONCEPTO *****

CANT. RENTISTICO	CONCEPTO	TOTAL CONCEPTO
1 50005-01-03	CAMBIO DE MODALIDAD Y MODIFICA	
12	MARCAS Y LEMAS COMERCIALES	103,000.00
	TOTAL :	\$ 103,000.00

SON: CIENTO TRES MIL PESOS

RESPONSABLE :

RECIBO DE CAJA APLICADO AL EXPEDIENTE No.

REIVINDICACIONES

1. Un compuesto que es formiato de O-desmetilvenlafaxina sólido.
2. Un compuesto según la Reivindicación 1 en donde el formiato de O-desmetilvenlafaxina es cristalino.
3. Un compuesto según la Reivindicación 1 o la Reivindicación 2 que tiene una endotermia a aproximadamente 152 °C.
4. Un compuesto según la Reivindicación 3 que tiene endotermias a aproximadamente 152 °C y a aproximadamente 232 °C.
5. Un compuesto según cualquiera de las Reivindicaciones 1 a 4 que tiene una tamaño de partícula entre aproximadamente 1,5 µm y aproximadamente 26 µm.
6. Un compuesto según cualquiera de las Reivindicaciones 1 a 5 que tiene una relación de aspectos de entre aproximadamente 1 y aproximadamente 44.
7. Un compuesto según cualquiera de las Reivindicaciones 1 a 5 que tiene una relación de aspectos de entre aproximadamente 1 y aproximadamente 4.
8. Un compuesto según cualquiera de las Reivindicaciones 1 a 5 cuya solubilidad en agua a temperatura ambiente es por lo menos aproximadamente 425 mg/ml.
9. Una composición farmacéutica que comprende formiato de O-desmetilvenlafaxina según se reivindica en cualquiera de las reivindicaciones 1 a 8 y un vehículo o excipiente farmacéuticamente aceptable.
10. Una composición farmacéutica según la Reivindicación 9 que comprende un polímero que controla la velocidad de liberación.
11. Una composición según la Reivindicación 10 que comprende entre aproximadamente 30 por ciento y aproximadamente 50 por ciento en peso de formiato de ODV y entre aproximadamente 25 por ciento y aproximadamente 70 por ciento en peso de un polímero que controla la velocidad de liberación.

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12. Una composición según la Reivindicación 10 o la Reivindicación 11 en donde el polímero que controla la velocidad de liberación es hidroxialquilcelulosa, hidroxipropilalquilcelulosa, óxido de polietileno, alquilcelulosa, carboximetilcelulosa; derivados hidrofílicos de la celulosa, o polietilenglicol.

13. Una composición según cualquiera de las Reivindicaciones 10 a 12 que además comprende un polímero que se hincha con el agua.

14. Una composición según la Reivindicación 13 que comprende entre aproximadamente un 20 por ciento y aproximadamente un 50 por ciento en peso de formiato de ODV, entre aproximadamente un 25 por ciento y aproximadamente un 45 por ciento de un polímero que controla la velocidad de liberación, y entre aproximadamente un 25 por ciento y aproximadamente un 45 por ciento de un polímero que se hincha con el agua.

15. Una composición según la Reivindicación 13 que comprende entre aproximadamente un 20 por ciento y aproximadamente un 35 por ciento en peso de formiato de ODV, entre aproximadamente un 25 por ciento y aproximadamente un 35 por ciento de un polímero que controla la velocidad de liberación, y entre aproximadamente un 25 por ciento y aproximadamente un 35 por ciento de un polímero que se hincha con el agua.

16. Una composición según la Reivindicación 13 que comprende aproximadamente un 23 por ciento en peso de formiato de ODV, aproximadamente 30 por ciento en peso de un polímero que controla la velocidad de liberación, y aproximadamente un 30 por ciento en peso de un polímero que se hincha con el agua.

17. Una composición según cualquiera de las Reivindicaciones 13 a 16 en donde el polímero que se hincha con el agua es un poliacrilato, polietilacrilato, etilacrilato, metilmetacrilato, cloruro de trimetilamonio etilmetacrilato polimetilacrilato, cloruro de trimetilamonio etilmetacrilato polietilacrilato, copolímero de dimetilaminoetilmetacrilato metacrilato, Carbopol 971P, Carbopol 974P o Carbopol 71G.

18. Una composición según cualquiera de las Reivindicaciones 13 a 16 en donde el polímero que controla la velocidad de liberación es hidroxipropilmetilcelulosa.

19. Una composición según cualquiera de las Reivindicaciones 13 a 16 en donde el polímero que se hincha con el agua es Carbopol 71G.

20. Una composición farmacéutica según cualquiera de las Reivindicaciones 1 a 9 que además comprende la venlafaxina.

21. Una forma de dosificación farmacéutica que comprende una cantidad terapéuticamente eficaz de formiato de O-desmetilvenlafaxina y un vehículo o excipiente farmacéuticamente aceptable.

22. Una forma de dosificación farmacéutica según la Reivindicación 21 en donde la forma farmacéutica es una formulación de liberación prolongada.

23. Una forma de dosificación farmacéutica según la Reivindicación 21 en donde la forma farmacéutica es una formulación de liberación controlada.

24. Una forma de dosificación farmacéutica según cualquiera de las Reivindicaciones 21 a 23 en donde la forma farmacéutica es una tableta o una cápsula.

25. Un método para preparar el formiato de O-desmetilvenlafaxina que comprende hacer reaccionar la O-desmetilvenlafaxina y ácido fórmico en etanol.

26. Un método según la Reivindicación 25 en el cual los reactantes están en cantidades estequiométricas.

27. Un método según la Reivindicación 25 en donde se usa un exceso de ácido fórmico.

28. Un método según la Reivindicación 27 en donde el exceso es entre aproximadamente 1,1 y aproximadamente 2,5 equivalentes.

29. Un método según cualquiera de las reivindicaciones 25 a 28 en donde la O-desmetilvenlafaxina está en un disolvente.

30. Un método según cualquiera de las reivindicaciones 25 a 28 en donde la O-desmetilvenlafaxina está disuelta en un disolvente.
31. Un método según la Reivindicación 30 en donde se disuelve una mezcla de O-desmetilvenlafaxina y ácido fórmico en un disolvente a una temperatura entre aproximadamente 55 °C y aproximadamente 80 °C.
32. Un método según cualquiera de las reivindicaciones 29 a 31 que comprende enfriar la mezcla de reacción hasta aproximadamente 5 °C y aproximadamente 6 °C por debajo del punto de turbidez a una velocidad de aproximadamente 1 grado por cada 3-5 minutos.
33. Un método según la Reivindicación 32 que comprende incubar la mezcla durante más de 1 hora a una temperatura aproximadamente 5 °C a 6 °C por debajo del punto de turbidez.
34. Un método según cualquiera de las Reivindicaciones 31 a 33 que además comprende enfriar la mezcla hasta entre aproximadamente 20 °C y aproximadamente 25 °C.
35. Un método según cualquiera de las Reivindicaciones 29 a 34 en donde el disolvente es etanol.
36. Un método según cualquiera de las Reivindicaciones 29 a 34 en donde el disolvente es tetrahidrofurano.
37. Un método según cualquiera de las Reivindicaciones 29 a 34 en donde el disolvente es acetona.
38. Un método según cualquiera de las Reivindicaciones 29 a 34 en donde el disolvente es 2-propanol.
39. Un método según cualquiera de las Reivindicaciones 32 a 34 en donde el punto de turbidez es aproximadamente 40 °C.
40. Un compuesto el cual es formiato de O-desmetilvenlafaxina producido de

acuerdo con un método según cualquiera de las Reivindicaciones 25 a 39, y el cual tiene una razón de aspectos entre aproximadamente 1 a aproximadamente 44.

41. Un compuesto el cual es formiato de O-desmetilvenlafaxina que tiene una endotermia a aproximadamente 152°C.

42. Un compuesto el cual es formiato de O-desmetilvenlafaxina que tiene endotermias a aproximadamente 152°C y a aproximadamente 232°C.

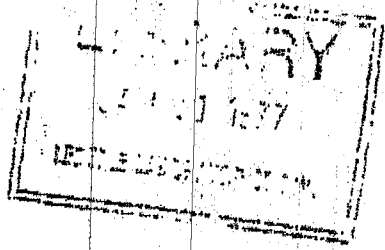
43. Un compuesto el cual es formiato de O-desmetilvenlafaxina que tiene un tamaño de partícula de aproximadamente 1.5 a aproximadamente 26 μm .

44. Un compuesto el cual es formiato de O-desmetilvenlafaxina que tiene una relación de aspectos de aproximadamente 1 a aproximadamente 44.

45. Un compuesto el cual es formiato de O-desmetilvenlafaxina que tiene una relación de aspectos de aproximadamente 1 a aproximadamente 4.

46. Un compuesto el cual es formiato de O-desmetilvenlafaxina de acuerdo con la reivindicación 1 que tiene una solubilidad en agua a temperatura ambiente de por lo menos aproximadamente 425 mg/mL.

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REVIEW ARTICLE

Pharmaceutical Salts

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D. C. MONKHOUSE^{*}

Keyphrases □ Pharmaceutical salts—general pharmacy, physicochemical properties, bioavailability, pharmaceutical properties, toxicology, review □ Salts, pharmaceutical—general pharmacy, physicochemical properties, bioavailability, pharmaceutical properties, toxicology, review □ Physicochemical properties—dissolution, solubility, stability, and organoleptic properties of pharmaceutical salts, review □ Bioavailability—formulation effects, absorption alteration and pharmacokinetics of pharmaceutical salts, review □ Toxicology—pharmaceutical salts, review

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The chemical, biological, physical, and economic characteristics of medicinal agents can be manipulated and, hence, often optimized by conversion to a salt form. Choosing the appropriate salt, however, can be a very difficult task, since each salt imparts unique properties to the parent compound.

Salt-forming agents are often chosen empirically. Of the many salts synthesized, the preferred form is selected by pharmaceutical chemists primarily on a practical basis: cost of raw materials, ease of crystallization, and percent yield. Other basic considerations include stability, hygroscopicity, and flowability of the resulting bulk drug. Unfortunately, there is no reliable way of predicting the influence of a particular salt species on the behavior of the parent compound. Furthermore, even after many salts of the same basic agent have been prepared, no efficient screening techniques exist to facilitate selection of the salt most likely to exhibit the desired pharmacokinetic, solubility, and formulation profiles.

Some decision-making models have, however, been developed to help predict salt performance. For example, Walkling and Appino (1) described two techniques, "decision analysis" and "potential problem analysis," and applied them to the selection of the most suitable derivative of an organic acid for development as a tablet. The derivatives considered were the free acid and the potassium, sodium, and calcium salts. Both techniques are based on the chemical, physical, and biological properties of these specific derivatives and offer a promising avenue for developing optimal salt forms.

Information on salts is widely dispersed throughout the pharmaceutical literature, much of which addresses the use of salt formation to prolong the release of the active component, thereby eliminating various undesirable drug properties (2-6). This review surveys literature of the last 25 years, emphasizing comparisons between the properties of different salt forms of the same compound. Included also is a discussion of potentially useful salt forms. Our purpose is twofold: to present an overview of the many different salts from which new drug candidates can be chosen and

Table 1—FDA-Approved Commercially Marketed Salts

Anion	Percent ^a	Anion	Percent ^a
Acetate	1.26	Iodide	2.02
Benzenesulfonate	0.25	Isothionate ¹	0.88
Benzoate	0.51	Lactate	0.76
Bicarbonate	0.13	Lactobionate	0.13
Bitartrate	0.63	Malate	0.13
Bromide	4.68	Maleate	3.03
Calcium edetate	0.25	Mandelate	0.38
Camelate ²	0.25	Mesylate	2.02
Carbonate	0.38	Methylbromide	0.76
Chloride	4.17	Methylbistriflate	0.38
Citrate	3.03	Methylsulfate	0.88
Dihydrochloride	0.51	Mucate	0.13
Edetate	0.25	Napsylate	0.25
Edisylate ³	0.38	Nitrate	0.64
Estolate ⁴	0.13	Pamoate (Embonate)	1.01
Esylate ⁵	0.13	Pantothenate	0.25
Fumarate	0.25	Phosphate/diphosphate	3.16
Glucopate ⁶	0.18	Polygalacturonate	0.13
Gluconate	0.51	Salicylate	0.88
Glutamate	0.25	Stearate	0.25
Glycylglycylsarcosinate ⁷	0.13	Subacetate	0.38
Hexylresorcinate	0.15	Succinate	0.38
Hydrobamine ⁸	0.25	Sulfate	7.45
Hydrobromide	1.90	Tannate	0.38
Hydrochloride	42.98	Tartrate	3.54
Hydroxynaphthoate	0.25	Teoclate ⁹	0.13
		Triethiodide	0.13
Cation	Percent ^a	Cation	Percent ^a
Organic:		Metallic:	
Berzathine ¹⁰	0.66	Aluminum	0.66
Chloroprocaine	0.38	Calcium	10.49
Choline	0.38	Lithium	1.64
Diethanolamine	0.66	Magnesium	1.31
Ethylenediamine	0.66	Potassium	10.82
Meglumine ¹¹	2.28	Sodium	61.97
Procaine	0.66	Zinc	2.95

^a Percent is based on total number of anionic or cationic salts in use through 1974. ¹ Camphorsulfonate. ² 1,3-Ethanedithiolate. ³ Lauryl sulfate. ⁴ Ethanesulfonate. ⁵ Glucoheptonate. ⁶ p-Glycylamidophenylsarcosinate. ⁷ N,N'-Di(2-hydroxyethyl)ethylenediamine. ⁸ 2-Hydroxyethanesulfonate. ⁹ 6-Chloro-2-thiophyllinate. ¹⁰ N,N'-Dibenzylethylenediamine. ¹¹ N-Methylglucamine.

to assemble data that will provide, for the student and practitioner alike, a rational basis for selecting a suitable salt form.

POTENTIALLY USEFUL SALTS

Salt formation is an acid-base reaction involving either a proton-transfer or neutralization reaction and is therefore controlled by factors influencing such reactions. Theoretically, every compound that exhibits acid or base characteristics can participate in salt formation. Particularly important is the relative strength of the acid or base—the acidity and basicity constants of the chemical species involved. These factors determine whether or not formation occurs and are a measure of the stability of the resulting salt.

The number of salt forms available to a chemist is large; surveys of patent literature show numerous new salts being synthesized annually. Various salts of the same compound often behave quite differently because of the physical, chemical, and thermodynamic properties they impart to the parent compound. For example, a salt's hydrophobicity and high crystal lattice energy can affect dissolution rate and, hence, bioavailability. Ideally, it would be desirable if one could predict how a pharmaceutical agent's properties would be affected by salt formation.

Tables I and II list all salts that were commercially marketed through 1974. The list was compiled from all agents listed in "Martindale The Extra Pharmacopoeia,"

26th ed. (7). Table I categorizes all salt forms approved by the Food and Drug Administration (FDA), while Table II lists those not approved by the FDA but in use in other countries. (Only salts of organic compounds are considered because most drugs are organic substances.) The relative frequency with which each salt type has been used is calculated as a percentage, based on the total number of anionic or cationic salts in use through 1974. Because of simple availability and physiological reasons, the monoprotonic hydrochlorides have been by far the most frequent choice of the available anionic salt-forming radicals, outnumbering the sulfates nearly six to one. For similar reasons, sodium has been the most predominant cation.

Knowledge that one salt form imparts greater water solubility, is less toxic, or slows dissolution rate would greatly benefit chemists and formulators. In some cases such generalizations can be made. Miller and Heller (8) discussed some properties associated with specific classes of salt forms. They stated that, in general, salt combinations with monocarboxylic acids are insoluble in water and lend themselves to repository preparations, while those of dicarboxylic acids confer water solubility if one carboxylic group is left free. Pamoic acid, an aromatic dicarboxylic acid, is an exception since it is used as a means of obtaining prolonged action by forming slightly soluble salts with certain basic drugs. Salas *et al.* (9) reviewed the use of this salt form in preparing sustained-release preparations. More recently, latentiation of dihydrostreptomycin (10

Table II--Non-FDA-Approved Commercially Marketed Salts

Anion	Percent ^a
Adipate	0.13
Alginate	0.13
Aminosalicylate	0.25
Anhydromethylenesulphate	0.13
Arecoline	0.13
Aspartate	0.25
Bisulfate	0.25
Butylbromide	0.13
Camphorate	0.13
Digluconate	0.13
Dihydrobromide	0.13
Dibuccinate	0.13
Glycerophosphate	0.82
Hemisulfate	0.13
Hydrofluoride	0.13
Hydroiodide	0.25
Methylenedis(salicylate)	0.13
Napadiazate ^b	0.13
Oxalate	0.25
Pectinate	0.13
Persulfate	0.13
Phenylethylbarbiturate	0.13
Picrate	0.13
Propionate	0.13
Thiocyanate	0.13
Tosylate	0.13
Undecanoate	0.13
Cation	Percent ^a
Organic	
Benzethamine ^c	0.33
Clemizole ^d	0.33
Diethylamine	0.33
Piperazine	0.98
Tromethamine ^e	0.33
Metallic	
Barium	0.33
Bismuth	0.98

^a Percent is based on total number of anionic and cationic salts in use through 1974. ^b 1,5-Naphthalenedisulfonate. ^c N-Benzylphenethylamine. ^d 1-p-Chlorobenzyl-2-pyrrolidin-1'-ylmethylenbenzimidazole. ^e Tris(hydroxymethyl)aminomethane.

using pamoic acid resulted in the formation of a delayed-action preparation. Numerous studies using pamoate salts are dispersed throughout the literature (11-15).

Alginic acid also has been used to prepare long-acting pharmaceuticals. Streptomycin alginate was prepared (16) and shown to be effective in sustained-release preparations. A striking example of a long-acting alginate salt is that of pilocarpine. When dispersed in sterile water and cast to a solid gel, this compound was found useful in the preparation of long-acting ophthalmic dosage forms (17). While liquid preparations of the alginate and hydrochloride salts possess similar miotic activity, studies showed that solid pilocarpine alginate flakes constricted pupil size more effectively and increased the duration of miosis significantly when compared with the liquid preparations. Solid dose pilocarpine may be more uniformly available, because it diffuses more slowly through the gel matrix which holds the drug in reserve. In contrast, drops of the commonly employed solution dosage form release the dose immediately to the conjunctival fluid.

Málek et al. (18) devised a unique way of prolonging action through salt formation; they showed that the distribution of several antibiotics could be markedly altered by merely preparing macromolecular salts. Since macromolecules and colloidal particles have an affinity for the lymphatic system, streptomycin, neomycin, viomycin, and

streptothricin were combined with high molecular weight compounds such as polyacrylic acids, sulfonic or phosphorylated polysaccharides, and polyuronic derivatives. Parenteral administration of these compounds produced low blood levels of the antibiotic for long periods, while lymph levels were high. (In comparison, streptomycin sulfate gave high blood levels but low lymph levels.) This alteration in distribution caused the streptomycin to prolong its passage through the body, since lymphatic circulation is quite slow.

The appropriate choice of a salt form has been found to reduce toxicity. It can be rationalized that any compound associated with the normal metabolism of food and drink must be essentially nontoxic. The approach of choosing organic radicals that are readily excreted or metabolized opened up a new class of substances from which to select a salt form. For example, certain salts of the strong base choline have proven to be considerably less toxic than their parent compound. The preparation and properties of choline salts of a series of theophylline derivatives were reported (19), and it was shown that choline theophyllinate possessed a greater LD₅₀ than theophylline or its other salts (20). It was postulated that this agent would be less irritating to the GI tract than aminophylline, because "its basic constituent, choline, is an almost completely nontoxic substance of actual importance to the physiologic economy." This evidence led to the preparation of choline salicylate (21) as an attempt to reduce the GI disturbances associated with salicylate administration. Clinical studies indicated that choline salicylate elicited a lower incidence of GI distress, was tolerated in higher doses, and was of greater benefit to the patient than was acetylsalicylic acid (aspirin).

Amino acids and acid vitamins also have been used as salt-forming agents. Based on the evidence that coadministration of amino acids with aminoglycoside antibiotics reduced their toxicity, a series of amino acid salts of dihydrostreptomycin was prepared (22). In all but one case, the acute toxicities of these salts were lower than the toxicity of the sulfate. The ascorbate and pantothenate also were synthesized and shown to be less toxic than the sulfate. Of the salts prepared, the ascorbate had the highest LD₅₀.

The vitamins most commonly used for forming salts exhibiting reduced toxicity are ascorbic and pantothenic acids. Keller et al. (23) were the first to use pantothenic acid as a means of "detoxifying" the basic streptomycin antibiotics. Parenteral administration of the pantothenates of streptomycin and dihydrostreptomycin had a significantly reduced incidence of acute neurotoxicity in cats as compared with the sulfates. Subsequent studies (24-28) supported this finding and showed that the pantothenates of neomycin and viomycin also are less toxic. The ascorbate of oleandomycin was synthesized and its pharmacological properties were reported (29). Upon intramuscular injection in rats, it produced less irritation than the phosphate.

p-Acetamidobenzoic acid, an innocuous metabolite of folic acid present in normal blood and urine, has been used in preparing salts. In particular, it yields stable salts with amines that otherwise tend to form hygroscopic products with conventional acid components (30).

Often the salt form is chosen by determining a salt

component that will pharmacologically antagonize an unfavorable property or properties exhibited by the basic agent. Salts of *N*-cyclohexylsulfamic acid are an example of the practical application of this approach. *N*-Cyclohexylsulfamic acid salts, better known as cyclamates, have a characteristic sweet, pleasing taste. Although presently under investigation by the FDA for potentially carcinogenic properties, salts incorporating this compound can render unpleasant or bitter-tasting drugs acceptable. For example, the cyclamates of dextromethorphan and chlorpheniramine exhibit greatly improved bitterness thresholds compared to commonly occurring salts (31). Furthermore, their stability in aqueous solution was described as good when maintained at a pH not greater than 4.

N-Cyclohexylsulfamic acid salts of thiamine hydrochloride and lincomycin also have been synthesized. Thiamine *N*-cyclohexylsulfamate hydrochloride was reported to have a more pleasant taste than other thiamine salts while having an equal or greater stability (32). Lincomycin cyclamate, shown to possess an enhanced thermal stability over its hydrochloride, was prepared (39) to test the hypothesis that reduced lincomycin absorption in the presence of small quantities of cyclamates was due to a simple metathetic reaction. However, this assumption was found not to be true. An extensive study of the preparation and characterization of cyclamic acid salts of several widely used classes of drugs including antihistamines, antibiotics, antitussives, myospasmolytics, and local anesthetics was reported (34, 35).

Various salts of penicillin and basic amine compounds have been formulated in an effort to produce a long-acting, nonallergenic form of penicillin. Since antihistamines appear to mitigate the symptomatology of penicillin reactions in some patients, coadministration of the two has been advocated. The preparation of the benzhydralamine salt of penicillin was an attempt to produce a repository form of penicillin with antiallergic properties (36). Blood levels achieved with this salt were comparable to those of penicillin G potassium; however, its antiallergic properties were not evaluated. In fact, the investigators noted that antihistamines can actually cause sensitization at times and stated that "despite their occasionally favorable influence on the symptoms of penicillin sensitivity, they contribute directly to the potential of drug sensitivity when co-administered with penicillin."

Silver salts of sulfanilamide, penicillin, and other antibiotics have been prepared and represent cases where the species (ions) are complementary. When aqueous solutions of the salts were applied topically to burned tissue, they yielded the combined benefits of the oligodynamic action of silver and the advantages of the antibacterial agents (37).

The use of 8-substituted xanthines, particularly the 8-substituted theophyllines, as salt-forming agents was first reported in the preparation of a series of antihistamine salts (38-41). Synthesis of these xanthine salts was an attempt to find a drug to counteract the drowsiness caused by the antihistamines with the stimulant properties of the xanthines. When an electronegative group is introduced into the xanthine molecule at the 8-position, the electron-drawing capacity of the substituent results in the creation of an acidic hydrogen at position 7. Thus, these

moderately strong acidic compounds can undergo salt formation with various organic bases.

The 8-halotheophyllines were the first group of xanthines studied as potential salt-forming agents. Since the report on the preparation of the 8-chlorotheophylline salt of diphenhydramine (42), synthesis of the 8-halotheophyllinates of a number of organic bases has been attempted. The 8-chlorotheophylline salts of quinine, ephedrine, and strychnine were prepared and characterized (43). These salts were less water soluble than the corresponding free alkaloidal bases. In a similar report, the 8-chlorotheophyllinates of three synthetic narcotics, meperidine, levorphanol, and metopon, were prepared (44).

Pharmacological and clinical studies involving the 8-bromotheophylline pyrilamine salt revealed the unusual diuretic properties associated with the 8-halotheophylline portion of the compound (45, 46). This finding initiated an investigation into the preparation of a soluble 8-bromotheophylline salt of high diuretic activity. With readily available amines, over 30 salts were synthesized and screened for diuretic activity (47). When tested against theophylline salts of the same amines, the 8-bromotheophyllinates showed greater activity in every case.

With the successful formation of 8-halotheophyllinates of organic bases, Morozowich and Bope (48) proposed that, if the halogen moiety was replaced with a more electronegative substituent such as a nitro group, a more acidic compound would be formed. Presumably, more stable salts would result and precipitation of the free xanthine derivative in the stomach would be less likely to occur. On this premise, they successfully prepared pharmacologically effective 8-nitrotheophyllinates of several pharmaceutically useful bases.

Diesel *et al.* (19), in their study of choline theophyllinates, prepared the 8-chloro-, 8-bromo-, and 8-nitrotheophylline salts of choline. Oral toxicity studies in mice showed that the LD₅₀ of the 8-nitrotheophyllinate was much greater than that of either 8-halotheophylline. In fact, it remained nonlethal at doses as high as 5 g.

Polygalacturonic acid, a derivative of pectin, has been used to prepare quinidine salts exhibiting reduced toxicity (49, 50). The compound possesses special demulcent properties and inhibits mucosal irritation. The rationale for use of this agent is to reduce the ionic shock to the GI mucosa resulting from the flood of irritating ions liberated by rapid dissociation of the conventional inorganic quinidine salts. Studies have shown that it is four times less toxic orally than the sulfate. This difference was attributed to the slower release of quinidine from the polygalacturonate.

Other compounds reported to be potentially useful as pharmaceutical salt forms are listed in Table III.

PHYSICOCHEMICAL STUDIES

Biological activity of a drug molecule is influenced by two factors: its chemical structure and effect at a specific site and its ability to reach—and then be removed from—the site of action. Thus, a knowledge of the physicochemical properties of a compound that influence its absorption, distribution, metabolism, and excretion is essential for a complete understanding of the onset and duration of ac-

Table III--Potentially Useful Salt Forms of Pharmaceutical Agents

Salt-Forming Agent	Compound Modified	Modification	Reference
Acetylsalicylic acid	Deoxycycline	Solubility	51
N-Acetyl-L-asparagine	Erythromycin	Solubility, activity, stability	52
N-Acetylcysteine	Doxycycline	Combined effect useful in pneumonia	53
Adipic acid	Alkylbiguanides	Prolonged action	54
N-Alkylsulfamates	Piperazine	Stability, toxicity, organoleptic properties	55
	Ampicillin	Absorption (oral)	56
	Lincomycin	Solubility	57
Anthraquinone-1,5-disulfonic acid	Cephalexin	Stability, absorption	58
Arbogalectan sulfate (arabino)	Various alkaloids	Prolonged action	59, 60
Arginine	Cephalosporins	Toxicity	61
	α -Sulfobenzylpenicillin	Stability, hygroscopicity, toxicity	62
Aspartate	Erythromycin	Solubility	63
Betaine	Tetracycline	Gastric absorption	64
Bis(2-carboxychromon-5-yloxy)alkanes	7-(Aminosalicyl)thienophyllines	Activity, prolonged prophylactic effect	65
Carnitine	Metformin	Toxicity	66
4-Chloro-m-toluenesulfonic acid	Propoxyphene	Organoleptic properties	67
Decanoate	Heptaminol	Prolonged action	68
Diacetyl sulfate	Thiamine	Stability, hygroscopicity	69
Dibenzylethylenediamine	Ampicillin	Prolonged action	70, 71
Diethylamine	Cephalosporins	Reduced pain on injection	72
Diguelacyl phosphate	Tetracycline	Activity	73
Dioctyl sulfosuccinate	Vincamine	Organoleptic properties	74
Embonic (pamoic) acid	Kanamycin	Toxicity	75
	2-Phenyl-3-methylmorpholine	Toxicity	76
Fructose 1,6-diphosphoric acid	Tetracycline	Solubility	77
	Erythromycin	Solubility	
Glucose 1-phosphoric acid, glucose	Tetracycline	Solubility	77
6-phosphoric acid	Erythromycin	Solubility	
L-Glutamine	Erythromycin	Solubility, activity, stability	52
Hydroxynaphthoate	Bephenium	Toxicity	78
2-(4-methoxyphenyl)ethylamine	Prostaglandin	Prolonged action	79
Isobutylamine	Theophylline	Stability	80
Leucyl sulfate	Vincamine	Organoleptic properties	81
Lysine	α -Sulfobenzylpenicillin	Toxicity, stability, hygroscopicity	62
	Cephalosporins		61
Methanesulfonic acid	Pralidoxime (2-PAM)	Solubility	82
N-Methylglucamine	α -Sulfobenzylpenicillin	Toxicity, stability, hygroscopicity	62
	Cephalosporins	Reduced pain on injection	72
N-Methylpiperazine	Phenylbutazone	Toxicity, faster onset of action	83
Morpholine	Cephalosporins	Reduced pain on injection	72
2-Naphthalenesulfonic acid	Propoxyphene	Organoleptic properties	84
Octanoate	Heptaminol	Prolonged action	68
Probenecid	Pivampicillin	Organoleptic properties	85
Tannic acid	Various amines	Prolonged action	86, 87
Theobromine acetic acid	Propoxyphene	Activity	88
2,4,6-Trimethoxybenzoate	Tetracycline	Organoleptic properties	89
	Heptaminol	Prolonged action	68
	Aspirin	Absorption (oral)	90
Tromethamine	Dinoprost (prostaglandin F _{2a})	Physical state	91

tion, the relative toxicity, and the possible routes of administration (2).

In a review in 1960, Miller and Holland (92) stated that "different salts of the same drug rarely differ pharmacologically; the differences are usually based on the physical properties." In a subsequent review (93), Wagner expanded upon this statement, asserting that, although the biological responses elicited by a series of salts of the same parent compound may not differ appreciably, the intensities of response may differ markedly.

The salt form is known to influence a number of physicochemical properties of the parent compound including dissolution rate, solubility, stability, and hygroscopicity. These properties, in turn, affect the availability and formulation characteristics of the drug. Consequently, the pharmaceutical industry has systematically engaged in extensive preformulation studies of the physicochemical properties of each new drug entity to determine the most suitable form for drug formulation. Published information concerning such studies, however, is sparse. Preformulation studies have been outlined, and the influence of the salt form on the volatility and hygroscopicity of an agent under investigation was discussed (94).

In one such study, methylpyridinium-2-aldoxime (pralidoxime) salts were investigated (95). This study set out to prepare a salt with water solubility adequate to allow intramuscular injection of a low volume (2-3 ml) therapeutic dose. The original compound, the methiodide, had the disadvantages of limited aqueous solubility and high potential toxicity, since its high iodide content could result in iodism. On the basis of physiological compatibility, better water solubility, favorable stability, and relatively high percentage of oxime, the chloride salt of pralidoxime was selected for therapeutic administration; it was claimed that "the anion used to form the salt can confer physical properties of importance and significance for the formulation and administration of the compound" (95).

Some physicochemical properties of a series of mineral acid salts of lidocaine also were determined (96). While the hydrochloride and hydrobromide were more hygroscopic, they were more soluble in a number of solvents than the nitrate, perchlorate, phosphate, or sulfate salts.

Dissolution Rate—The dissolution rate of a pharmaceutical agent is of major importance to the formulator. In many cases, particularly with poorly soluble drugs, this characteristic best reflects the bioavailability of the com-

pound. As a rule, a pharmaceutical salt exhibits a higher dissolution rate than the corresponding conjugate acid or base at an equal pH, even though they may have the same equilibrium solubility. The explanation for this result lies in the processes that control dissolution.

Dissolution can be described by a diffusion layer model¹ in terms of an equation developed by Nernst and Brunner (97):

$$\frac{dW}{dt} = \frac{DS}{h} (C_s - C) \quad (\text{Eq. 1})$$

where W is the mass of the solute dissolved at time t , dW/dt is the rate of mass transfer per unit time, D is the solute molecule-diffusion coefficient, S is the surface area of the dissolving solid, h is the diffusion layer thickness, C is the concentration of the drug in the bulk solution at time t , and C_s is the saturation solubility of the solute in the diffusion layer.

The driving force for dissolution in Eq. 1 is the difference between the saturation solubility of the drug and the concentration of the drug in the bulk fluid. If the drug is not rapidly absorbed after it dissolves, then C , the concentration in the bulk solution, approaches C_s and the dissolution rate is retarded. When this occurs, absorption is "absorption rate" limited (or "membrane transport" limited). If the absorption rate is rapid (or if the absorption mass transfer coefficient is much larger than DS/h of Eq. 1), however, C becomes negligible compared to C_s and dissolution occurs under "sink" conditions. Absorption is then said to be dissolution rate limited, which is what occurs with most poorly soluble drugs. In either case, an increase in C_s , as in salt formation, increases dissolution.

Salts often speed dissolution by effectively acting as their own buffers to alter the pH of the diffusion layer, thus increasing the solubility of the parent compound, C_s , in that layer over its inherent solubility at the pH of the dissolution medium. Hence, dissolution is controlled by solubility in the diffusion layer which, in turn, is determined by the pH of that layer. The influence of K_{sp} on the solubility term, C_s , and dissolution rate, should an accumulation of ions be allowed to occur, will be treated later.

Nelson (98), in a study of theophylline salts, was the first to show the correlation between diffusion layer pH and dissolution rate. The major impact that this study had on the pharmaceutical sciences was its conclusion that, if other factors remained constant, the dissolution rate of a compound determined the rate of buildup of blood levels with time and the maximum levels obtained. Those salts of the acidic theophylline with high diffusion layer pH's had greater *in vitro* dissolution rates than those exhibiting a lower diffusion layer pH. And, indeed, the rank order of dissolution rates correlated well with clinically determined blood levels. Presumably, the higher pH in the diffusion layer retards hydrolysis of the salt, thereby maintaining the anionic charge of the theophyllinate ion. This report led to many additional studies which illustrate the influence of the salt form on dissolution and the beneficial effects of changing nonionized drugs into salts.

Juncher and Raaschou (99) demonstrated that the rank order of peak blood levels of penicillin V, obtained upon

administration of three different salts and the free acid, was the same as the rank order of their rates of dissolution *in vitro*. While the investigators ascribed these differences to the solubility properties of the salts, their experiments actually compared dissolution rates, not solubilities. The relative order of dissolution rates and mean maximal blood levels was: potassium salt > calcium salt > free acid > benzathine salt.

Nelson (100) determined dissolution rates for several weak acids and their sodium salts in media whose pH's represented GI fluids. In all cases, the sodium salt dissolved more rapidly than the free acid. This finding resolved the misconception that absorption of drugs is related only to solubility in the appropriate medium; rather, solubility affects absorption only to the extent that it affects dissolution rate. Absorption of drugs is a dynamic process, and the ultimate solubility of a drug in fluid at absorption sites is of limited consequence since absorption prevents the attainment of saturated solutions. Therefore, dissolution rate, more than solubility, influences absorption since it is a preceding process.

In two subsequent studies, Nelson and coworkers further illustrated the effects of changing nonionized drugs into salts. A report concerning tolbutamide (101), a weak acid, showed that the initial dissolution rate of tolbutamide sodium was approximately 5000 times more rapid than the free acid in acidic media and 300 times more rapid in neutral media. This difference, measured *in vitro*, reflected the differences observed between the free acid and the salt when administered to human subjects. Oral administration of tolbutamide sodium produced an immediate drop in blood sugar comparable to that produced by intravenous injection of the salt, while the slowly dissolving tolbutamide produced a smooth, sustained fall in blood sugar (102).

Correlation of urinary excretion rates and dissolution rates of tetracycline and some of its acid salts also was demonstrated by Nelson (103). The salts that exhibited greater *in vitro* dissolution rates showed greater urinary excretion rates, indicating more rapid absorption.

Benet (104), in a discussion of the biopharmaceutical basis for drug design, referred to the influence of the salt form on dissolution. He compared the dissolution rates of tetracycline and tolbutamide and their salts, as reported in the studies previously cited, and explained why the rates differ at the pH's exhibited by physiological fluids.

Although salt formation usually increases the dissolution rate of a drug, studies with aluminum acetylsalicylate (105, 106), warfarin sodium (107), and benzphetamine pamoate (108) showed that administration of the salt slowed dissolution of the drug and subsequent absorption compared to the nonionized form. This decrease appeared to result from precipitation of an insoluble particle or film on the surface of the tablet. Such a phenomenon decreases the effective surface area and prevents deaggregation of the particles. Theoretical considerations of the processes controlling dissolution of an acid salt of a base (108) and the sodium salt of a weak acid (109, 110) in reactive media have been discussed.

Tablet processing and various formulation factors can decrease the dissolution rate of a salt in human gastric juice over its nonionized form (111). Granulation and tableting caused the dissolution rate of phenobarbital sodium to

¹ The authors recognize the existence of other models; this one was chosen simply for illustrative purposes.

decrease but had the opposite effect on phenobarbital. Therefore, as a tablet dosage form, the dissolution rate of the sodium salt was slower than that of the free acid. These results were attributed to differences in the disintegrating properties of the tablets; in some instances, rapid dissolution may in fact be a problem for very soluble drugs.

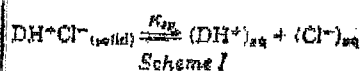
Others have illustrated a phenomenon that decreases the dissolution rate of a salt below that of its nonionized form. Lin et al. (112) studied the relationship between salts and biological activity by dissolving three salts and the free base of an experimental antihypertensive in water, 0.1 N HCl, and pH 7.2 phosphate buffer. The dissolution rate of the monohydrochloride salt was lower than that of the free base in 0.1 N HCl and higher than the free base in both water and phosphate buffer. These authors ascribed this variation to the common ion effect and substantiated it experimentally. Although the biological activity of the monohydrochloride was greater than that of the free base, the implications of altered absorption characteristics on the activity of any other hydrochloride salt in GI fluids must be considered. Similar results also were reported for hydrochloride salts of some tetracyclines (113).

Some consideration must be given to the influence of salt formation on oral toxicity, which often reflects the relationship between the *in vivo* dissolution rate and the appearance of drug in the circulation (114, 115). Morozowich et al. (114) showed that the relative toxicities of a series of salts of a drug reflect the rate of absorption, providing the salt-forming agents themselves are relatively nontoxic. They stated that "when absorption is rate-limited by dissolution of the salt in the gastrointestinal tract, as will be the case with slowly soluble salts, the toxicity of a slowly dissolving salt will most probably be lower than that of a more rapidly dissolving salt." The implications of salt formation on toxicology will be discussed under *Toxicological Considerations*.

Several reviews dealt with the influence of the dissolution rate on drug availability and, in particular, salt effects (116, 117). Other reports illustrating the influence of salts and salt form on dissolution rate are listed in Table IV.

Solubility—Knowledge of the solubility characteristics of a pharmaceutical agent is essential, because solubility is usually an important factor in the pharmacokinetic profile, the chemical stability, and, ultimately, the formulation of the drug. As discussed previously, it is certainly a primary factor in controlling dissolution rates. The solubility of a compound depends basically upon the physical and chemical properties of the solute; e.g., a lower melting point for a compound within a series reflects a decreased lattice energy, which would suggest a higher solubility. Solubility depends as well upon such elements as temperature, pressure, solvent properties (such as resulting pH), and, to a lesser extent, the state of subdivision of the solute.

An important solvent property which is often overlooked involves the common ion effect; in particular, hydrochloride salts of drugs often exhibit less than desirable solubility in gastric juice because of the abundance of chloride ions. The equilibrium involved is shown in Scheme I.



Salt formation is perhaps one of the first approaches

Table IV—Additional References on Salt Form and Dissolution Rate

Topic	Reference
Dissolution rate of mixtures of weak acids and tribasic sodium phosphate	118
Physiological availability and <i>in vitro</i> dissolution characteristics of some solid dosage formulations of aminosalicylic acid and its salts	119
Biopharmaceutics, rate of dissolution: chronological bibliography	120
Biopharmaceutics: rate of dissolution <i>in vitro</i> and <i>in vivo</i>	121
Dissolution tests and interpretation of anomalies observed in the dissolution process of sulfaquinoxaline based on salt formation	122
Influence of the dissolution rate of lithium tablets on side effects	123
Dissolution kinetics of drugs in human gastric juice	124
Comparison of dissolution and absorption rates of different commercial aspirin tablets	125
<i>In vitro</i> dissolution rates of aminorex dosage forms and their correlation with <i>in vitro</i> availability	126

considered as a means of increasing a compound's water solubility. As with dissolution rates, however, salt formation does not always confer greater solubility. Liberally dispersed throughout the pharmaceutical literature are studies that compare the solubilities of different salt forms of the same compound with those of its free acid or base (Table IV). Selection of the salt form exhibiting the desired solubility properties is critical, since these properties often dictate the formulation characteristics of the drug.

Phase solubility techniques were used to study the formation of complex salts of triamterene (127). The results indicated that the organic acid salts of basic drugs, such as amines, were more soluble in water than the corresponding inorganic (halide) salts. This consideration is important in the synthesis and selection of a salt form that will exhibit enhanced bioavailability and desirable formulation characteristics.

The hydrogen-ion concentration can significantly affect the solubility of a salt. Anderson (128) discussed the influence of pH on the solubility of pharmaceuticals. Mathematical relationships between pH and solubility of therapeutically useful weak acids and bases and their salts were given along with some considerations in the formulation of solutions of these particular agents.

An extensive study on the solubility interrelationships of the hydrochloride and free base of two pharmaceutically useful amines was reported (129). Mathematical equations describing the total solubility at an arbitrary pH in terms of the independent solubilities of the hydrochloride and free base species and the dissociation constant of the salt were derived and fitted to experimental data with good results. This report elucidated the point that, while the solubility of the amine hydrochloride generally sets the maximum obtainable concentration for a given amine, the solubility of the free base and the pKa determine the maximum pH at which formulation as a solution is possible (assuming that the desired concentration exceeds the free base solubility). Shifting the pH-solubility profile to higher pH values for formulation purposes may require increasing the solubility of the free base. This increase might be accomplished by using an appropriate cosolvent. Since the dissociation characteristics of carboxylic acids and other acidic organic species are similar to those of organic hydrochlorides, it is expected that the pH-solubility profiles

of these organic acids, although reversed, can be characterized theoretically using the same treatment.

Several reports showed that the structure of an organic salt-forming radical influences the solubility of the resulting salt. The water solubilities of 16 salts (carboxylates, sulfates, sulfamates, and phosphates) of the weak base erythromycin were dependent on the size of the alkyl group of the acid (130). In a study with *N*-alkylsulfamates of lincomycin (66), a similar phenomenon was observed: solubility of these salts decreased as the size of the alkyl group attached to the acidic function increased.

Senior (131), in a study on the formulation and properties of the antibacterial chlorhexidine, determined the water solubilities of 35 salts and the free base. He found that inorganic salts had remarkably low solubilities while those of the lower aliphatic acids proved to be somewhat more soluble. Hydroxylation of the acid increased solubility, since salt formation with polyhydroxy acids, particularly the sugar acids, conferred extensive water solubility to the molecule.

Several investigators reported the influence of the solubility of a drug on its formulation and subsequent availability from the dosage form. In a discussion of the preparation and formulation of epinephrine salts in an aerosol system using liquefied gas propellants, Sciarra et al. (132) pointed out that the solubility characteristics of the agent are important in two respects. First, the solubility of the therapeutically active ingredient in the various propellants is an important consideration if the product is to be used for either local action in the lungs or systemic therapy. Second, the solubility of the drug in extracellular fluids plays an important role in selection of the compound. The bitartrate, malate, maleate, and fumarate salts of epinephrine were prepared and subjected to solubility and stability studies. While all salts had similar partition coefficients, the solubility of the maleate in several propellants and its stability in formulated aerosols made it the drug form of choice.

Ephedrine hydrochloride was more rapidly released than the free base from theobroma oil suppositories containing different surfactants (133). This enhanced rate of release (dialysis) was ascribed primarily to the greater aqueous solubility of the hydrochloride, which solubilized faster from the oil-in-water emulsion, whereas the ephedrine alkaloid base tended to remain behind in the oil phase.

The solubility of the active ingredient in ointment bases can dramatically influence its diffusion properties. A study of salicylic acid and its sodium salt showed that the diffusion of both was very low from hydrophobic bases, whereas the solubility of the drug significantly affected the diffusion from hydrophilic bases. The more soluble sodium salicylate diffused much faster from these latter bases than did salicylic acid (134).

Additional references on the relationship of salt form and solubility are listed in Table V.

Organoleptic Properties.—Modern medicine requires that a pharmaceutical formulation be efficacious, safe, stable, and acceptable to the patient. Of primary importance in the development of oral dosage forms is taste acceptability. This factor presents no major problems when the drug is to be administered as a tablet or a capsule and swallowed as a unit but is clearly a prominent factor in

Table V—Additional References on Salt Form and Solubility

Topic	Reference
Influence of solubility on the rate of GI absorption of aspirin	135
Effect of dosage form upon the GI absorption rate of salicylates	136
Physical-chemical properties of polyene macrolide esters and their water-soluble salts	137
Isolation and reaction products of orotic acid and amines and their solubility in water	138
Solubility and stability of erythromycin salts	139
Studies on pharmaceutical preparations of orotic acid: water-soluble properties of orotic acid salts	140
Solubility of antibiotics in 24 solvents	141, 142
Solubility of antibiotics in 26 solvents	143

patient acceptability when it is to be administered as a liquid, chewable tablet, or lozenge.

Since taste is a chemical sense, a substance must be dissolved if it is to elicit a taste sensation—either by taking it as a solution or by its dissolving in the saliva. Therefore, one method used to minimize undesirable organoleptic properties of pharmaceuticals involves the preparation of a poorly soluble salt form of the drug such that the saturation concentration is less than the taste threshold.

Erythromycin estolate (lauryl sulfate) has approximately one-twelfth the solubility of the free base, is tasteless, and is useful in the formulation of oral suspensions (144). A study on erythromycin salts showed that the bitterness level was dependent on two properties: (a) the water solubility of the salt, which is dependent on the size of the alkyl group attached to the acid function; and (b) the strength of the acid used to form the salt, i.e., the stability of the salt (130). The stearyl sulfamate salt possessed the most desirable organoleptic properties.

Many problems concerned with formulation and stability of topical and oral pharmaceuticals containing bacitracin have been overcome by incorporating bacitracin into the formulation as its zinc salt. One distinct advantage over the parent compound is its lack of taste, caused by its relative insolubility. Thus, it is the preferred drug form for preparations where taste is a factor (145). Taste panel evaluations of the comparative bitterness of bacitracin zinc and bacitracin indicate that the taste of the zinc salt is more easily masked and that the presence of a bitterness-masking adjuvant, such as sucrose, increases the bitterness threshold ratio differences between the two compounds even further (146).

Propoxyphene napsylate, nearly water insoluble, is only slightly bitter to the taste as compared to the highly water-soluble hydrochloride (147) and can be readily formulated into a flavored aqueous suspension. The taste of these suspensions can be improved significantly by the addition of a common ion (sodium or calcium napsylate) to depress solubility further.

A newer approach to the improvement of drug palatability has been to form insoluble salts with ion-exchange resins. Several investigators described and tested the practical application of this method (148-150). Spross et al. (149) outlined the conditions necessary for improving the palatability of a drug by adsorbing it onto an ion-exchange resin without appreciably modifying its pharmacological effects. They found that: (a) the degree of drug release from the ion-exchange adsorbate depends on the

equivalent quotient between the electrolytes in the surrounding fluid and the ionic drugs, (b) the amount of ions is far less in the saliva than in the gastric juice (the temporary electrolyte contents can be estimated at 0.05 mEq in the saliva and at 10 mEq in the gastric juice), and (c) the exchange rates should allow the equilibria to be attained within a fairly short period. Insoluble drug resins formed between dextran gel² cation exchangers and several basic drugs were in many cases much more pleasant tasting than their parent compounds. Furthermore, release of the drug from the ion-exchange adsorbate was quite rapid and complete under conditions prevailing in the GI tract.

Similar findings were reported using a polymethacrylic acid ion-exchange resin (150). In addition, coating the adsorbate particles with a 4:1 ethylcellulose-hydroxypropyl methylcellulose mixture further reduced bitterness. While *in vitro* release from the uncoated resinate was rapid and complete, release from coated adsorbates varied with the extent of coating.

Another approach to improving the taste properties of pharmaceutical agents is to prepare a pleasant-tasting soluble salt of a poor-tasting parent drug. This approach often can be very difficult, however, since solubilization of the parent compound usually imparts its unpleasant taste to the preparation. Nevertheless, some success has been reported using the artificial sweeteners cyclamate sodium and saccharin.

As described earlier, formation of *N*-cyclohexylsulfamate salts of several drug substances has produced better tasting derivatives with enhanced solubility properties (31, 32). The physicochemical and toxicological properties of benzalkonium saccharinate and a series of saccharinates of other quaternary ammonium compounds were reported (151). While conventional quaternary ammonium compounds have a very bitter taste, their saccharin analogs are sweet.

Potassium salts frequently possess an unpleasant taste and a metallic aftertaste. The palatability of some potassium salts in flavored vehicles was reported (152); while the salts had similar taste thresholds at effective therapeutic levels, all potassium salts exhibited inferior palatability.

Table III includes several samples of other salts that exhibit an improved taste relative to their free acid or base forms.

Stability—The chemical and physical stability of a pharmaceutical must be known, because it can influence the choice of dosage form, the manufacturing and packaging, and the therapeutic efficacy of the final preparation. Systematic determination of the thermal stability, solution stability (at various pH's), and light sensitivity of a drug and its derivatives, both alone and in the presence of common additives, provides essential input toward selecting the most suitable derivative and dosage form.

Depending on the route of degradation, different salt forms impart different stability characteristics to the parent drug by various mechanisms. Most commonly used are sparingly soluble salts which, when used in the formulation of suspensions, reduce the amount of drug in solution and, hence, its degradation. Differences in hygroscopicity of several salts influence the stability of the

drug in the dry state. In some cases, the salt-forming radical itself enhances the stability of the parent agent.

The stability of penicillin G and its salts has been widely studied due to the drug's therapeutic importance and its characteristic instability. Schwartz and Buckwalter (153) described some of the stability characteristics of this antibiotic, stating that, with present techniques, a solution of penicillin cannot be made stable for more than 2 weeks, even at refrigerator temperatures. They also discussed the use of suspensions of sparingly soluble amine salts in aqueous vehicles as a means of "allowing marketing of a 'ready-made' penicillin product." Procaine, benzathine, and hydrabamine salts are marketed, and their acceptable stability as aqueous suspensions is based mainly on their insolubility and the minimization of degradation in solution.

A theoretical treatment of the solubility of these salts was presented in which equations were derived for calculating the solubility as a function of pH and the pH of minimum solubility (154, 155). These equations are based on the mass action law and its relationship to the ionization constants of the amine and the penicillin and the solubility of the salt in water. Since the salt in solution is partially dissociated, further suppression of the solubility may be achieved by the common ion effect. Swintosky *et al.* (156) demonstrated this effect with penicillin G procaine by adding procaine hydrochloride to the preparation and further enhancing its stability. The 8-chlorotheophylline salt (or complex) of penicillin G was reported to be water soluble, yet stable in solution (157). Since 8-chlorotheophylline is acidic, it has been postulated that a buffer effect could account for the stabilization of this "salt."

While penicillin G procaine is more stable in aqueous vehicles, it is less thermally stable than the sodium or potassium salts, decomposing if heated much above 60°. The sodium and potassium salts are known to withstand heating up to 100° for 4 days with little loss in potency (158). This behavior might well be due to differences in melting points—*viz.*, 106° for penicillin G procaine and ~215° dec. for the potassium salt.

Since hydrolysis of penicillin is dependent on moisture content, preparations in which moisture is rigorously excluded are quite stable in the dry state. A study on the effect of moisture on penicillin salts found the calcium salt to be less hygroscopic than the sodium salt and, hence, more stable in moist atmospheres (159). Similarly, penicillin G potassium is also much less hygroscopic than penicillin G sodium and has become the preferred form for marketing in the dry state (160).

Several studies reported the relative stabilities of thiamine salts, particularly the hydrochloride and the mononitrate (161-163). The mononitrate is observed to be less hygroscopic and is accordingly much less water soluble than the hydrochloride. Investigations of various preparations including compressed tablets, multivitamin capsules, and dry-filled vitamin B complex capsules at various temperatures showed that the mononitrate was more stable than the hydrochloride (164, 165). The stabilities of numerous thiamine salts were studied in aqueous solution and in dry powder preparations with various excipients (166, 167). In aqueous solution, the resulting pH was the chief factor controlling hydrolysis and oxidative decomposition of thiamine salts; their stability as powder

² Sephadex.

preparations was related to their aqueous solubility, with the sparingly soluble salts being more stable (and presumably less hygroscopic).

An orally administered drug must be stable in acidic solution because it generally must pass intact through the acidic environment of the stomach if it is to exhibit therapeutic blood levels. The advantage of erythromycin estolate over the free base lies in its low solubility in gastric juice, which enables it to be administered with food without any decrease in attained blood levels. The salt is more stable in the stomach because it remains undissolved. Therefore, it retains its potency even when exposed to acidic environments for extended periods (144).

In a study on the preparation and characterization of lincomycin cyclamate (33), it was noted that the cyclamate salt had an enhanced thermal stability over the hydrochloride. In a subsequent report (168), differential thermal analysis and thermogravimetric analysis showed that while the hydrochloride easily undergoes thermal degradation, the cyclamate anion confers a considerably greater thermal stability on the lincomycin moiety.

Mullins and Maccek (169) showed that the physical and chemical stability of the calcium salt of novobiocin makes it the form of choice for the formulation of a liquid preparation of the antibiotic. The amorphous calcium novobiocin salt proved to be tasteless, yet fully biologically active and perfectly stable in aqueous suspension. Neither the sodium salt nor the free acid is suitable; the sodium salt cannot be formulated in a liquid due to its chemical instability, while the crystalline free acid is not absorbed from the GI tract. Amorphous novobiocin is absorbed but is metastable in solution and slowly converts to the unabsorbed crystalline form.

Other reports of alterations in stability characteristics due to salt formation are listed in Table VI.

Miscellaneous Properties—The salt form has been reported to influence other physicochemical properties of a drug substance. Studies illustrating the effect of the salt-forming radical on surface tension, deaggregation behavior, and ion-pair extraction have appeared.

The influence of the anion on the absorption processes of two charged species, dextromethorphan and tetracycline, was studied in the rat stomach (186, 187). A linear relationship existed between the rate of absorption from buffer solutions of the anions under investigation and their surface tensions. Thus, the absorption process was related to the surface activity of the various salts and not to their lipid solubilities. This change of surface activity with the buffer (or salt) species is similar to the results reported in a study of the surface activity of various phenothiazine salts (188).

The antibacterial chlorhexidine possesses surface activity. A study of the colloidal properties of some chlorhexidine salts showed that the counterion can affect the critical micelle concentration of a surface-active agent, and this effect was usually associated with a change in micellar size (189).

The deaggregation behavior of a relatively insoluble acid and its sodium salt was studied, and deaggregation was postulated to be a possible rate-limiting step in the absorption of a drug from a dosage form (190). While no direct comparisons of the two forms were made, inspection of the data shows that the deaggregation rate of the salt

Table VI—Additional References on Salt Form and Stability

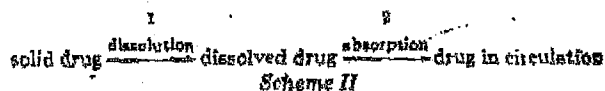
Topic	Reference
Stability of chlorhexidine solutions	170
Stability of chlorhexidine when autoclaved	171
Anhydrotetracycline and 4-epianhydrotetracycline in marketed tetracycline and aged tetracycline products	172
Solid-state stability of some crystalline vitamin A compounds	173
Physicochemical studies on the stability of penicillin salts	174
Light sensitivity of tetracyclines	175
Hygroscopic properties, thermostability, and solubility of oleandomycin salts	176
Stability of crotonic acid and its amine salts in aqueous solution	177
Some factors influencing the stability of tablets (aspirin)	178
Stability of aqueous solutions of sodium aminosalicylate	179
Hygroscopic properties of various preparations of erythromycin	180
Physicochemical studies on the decomposition of aminosalicylic acid and its salts	181
Stabilities of aqueous solutions of 2-diethylaminoethyl-3-methyl-2-phenylvalerate hydrochloride and its methobromide	182
Investigation of some properties of penicillin G salts	183
Stability of ferrous iron tablets on storage	184
Stability of aspirin aluminum compounded with antacids	185

was considerably more rapid than that of the free acid in equivalent dosage forms. Therefore, if absorption is dependent on the dissolution rate, which in turn is dependent on the deaggregation rate, the salt should produce the highest and earliest blood levels. On the other hand, it is possible that hygroscopic (and deliquescent) salts can absorb atmospheric moisture, cause a sticky surface, and inhibit deaggregation.

Higuchi and coworkers presented an extensive study on the physicochemical basis of the ion-pair extraction of pharmaceutical amines. Distribution ratios of dextromethorphan (191) and chlorpheniramine (192) between an organic layer and water were highly dependent on the concentration and nature of the anion present. Less hydrophilic anions yielded more readily extractable ion-pairs. A study of the thermodynamic properties, enthalpy, free energy, and entropy, involved in the extraction equilibria of dextromethorphan ion-pairs indicated that the entropy change associated with transfer of the different anions between phases is the main controlling factor in the extraction process (193).

BIOAVAILABILITY

Most drugs prescribed in the United States are administered in solid and polyphasic dosage forms. Consequently, dissolution of the drug must precede the absorption process. The simplest model that adequately describes this process is shown in Scheme II.



Since the dissolution rate is generally slow for drugs with poor solubility, Step 1 is frequently rate limiting in the overall absorption process. As a result, the onset, intensity, duration of pharmacological activity, and, hence, bioavailability are affected by changes in dissolution rate. As discussed previously, administering a salt of the parent drug often proves to be an effective means of altering dissolution rate and absorption.

Table VII—Additional References on Bioavailability and Formulation Effects

Topic	Reference
Effects of various substances on the absorption of tetracycline in rats	197
Effects of dosage form upon the GI absorption rate of salicylates	198
Formulation of <i>in vivo</i> and <i>in vitro</i> release of theophylline aminoisobutanol in a prolonged-action system	199
Exchange resin salts for oral therapy: carbinoxamine entrapment of dihydrostreptomycin by pantoate ionization	10
Distate ophthalmic dosage systems in effecting prolonged release of pilocarpine in the cul-de-sac	17
Absorption of erythromycin: various pharmaceutical forms	200
Comparative study of the absorption of drugs from old and new rectal preparations	201

Formulation Effects—Choice of the salt form of a drug may have a pronounced effect on the formulation of the parent compound. For example, Fenton and Warren (194) found there was no release of medicament from proflavine in BPC, a water-in-oil emulsion containing 0.1% flavine as the hemisulfate salt. They also investigated release of various salts of proflavine with aliphatic carboxylic acids from water-in-oil cream emulsions. Salts of the water-soluble, oil-insoluble "lower" acids, such as formic and acetic acids, showed very poor release in a water-in-oil cream. The "higher" acid salts (e.g., stearic, caproic, cyclohexanecarboxylic, and caprylic) showed increased diffusion from similar emulsions since these salts are soluble in both water and oil. Their release was even greater from oil-in-water emulsions, however, in agreement with their preferential oil solubility. The stearate salt provided the most effective water-in-oil emulsion. The primary factor responsible for diffusion of proflavine from a water-in-oil cream is the low hydrophilic-lipophilic balance conveyed to the salt by the acid. This finding illustrates the desirability of carefully selecting the salt anion of a cationic drug in lieu of the nature of the dosage form.

Studies of the effect of formulation on the bioavailability of warfarin sodium relative to warfarin yielded interesting results (107, 195). Absorption of warfarin upon administration of the sodium salt as a lactose-base tablet was no different than that from a similar formulation of the free acid. However, absorption was further depressed when the salt was formulated with starch instead of lactose. Later results indicated that the *in vitro* water dissolution rate of a warfarin sodium tablet was 350 times that of a slowly dissolving warfarin tablet formulation, yet the latter exhibited complete absorption *in vivo*. The virtual inability of warfarin in acidic gastric fluids precluded its absorption from the stomach. However, the strongly acidic environment was necessary for tablet disintegration, which, in turn, was critical for absorption. Following initial exposure to HCl, *in vitro* dissolution of the warfarin tablet in buffer was 14 times faster than that of the sodium salt. This result explained the otherwise contradictory blood level data. Therefore, absorption was ultimately dependent upon gastric emptying rate and gastric pH as well as the formulation disintegrated properly in the stomach. Rectal absorption of aspirin, aspirin aluminum, and

calcium carbaspirin from several suppository bases was studied in dogs (196). The absorption of aspirin aluminum from either cocoa butter or a polyethylene glycol base was poor. While the maximum salicylate levels produced by aspirin and calcium carbaspirin from the cocoa butter base occurred at a later time than from the other bases studied, minimal plasma levels were exhibited by a polysorbate 61 base formulation. The highest peak and largest area under the blood level curve were seen with calcium carbaspirin in a vegetable fatty acid glyceride base. The poor absorption of aspirin aluminum from suppositories was not unexpected since it is poorly soluble. Furthermore, as pointed out for aspirin aluminum tablets (105, 106), an insoluble aluminum compound may form on the surface of the dissolving drug, further impeding its dissolution rate and bioavailability.

Additional references on bioavailability and formulation effects are given in Table VII.

Absorption Alteration—Several years ago, clinicians claimed that certain salts of theophylline were therapeutically preferable to other salts or to the free acid (202-204). For example, Schlager *et al.* (204) found higher blood theophylline levels after administering uncoated tablets of theophylline ethylenediamine than were observed with enteric-coated tablets of choline theophyllinate. These results were at variance with the *in vivo* work of Gagliani *et al.* (202), who found that the oral ingestion of choline theophyllinate produced significantly higher blood levels than the ethylenediamine salt. This apparent discrepancy could be explained by the formulation effects of tablet coating, etc., which was not discussed in the work of Gagliani *et al.* In another study, a slightly more rapid rise in blood concentration and a greater area under the curve were observed with theophylline isopropanolamine than with theophylline ethylenediamine (203). It was suggested that the difference was a result of the greater water solubility of the isopropanolamine salt.

The *in vitro* dissolution rates of the choline and isopropanolamine salts of theophylline have been observed to be three to five times greater than the ethylenediamine salt, depending on the dissolution medium (98). It has been suggested that these differences in dissolution rate are consistent with, and offer an explanation for, the clinical results.

In a comparative study of the absorption of ampicillin trihydrate and ampicillin potassium following oral administration (205), the potassium salt yielded 37% higher peak levels and a larger area under the curve. Only 36% of the administered ampicillin trihydrate was absorbed while 53% of the potassium salt was absorbed. Determining the percentage of each drug eliminated in the urine showed that 39% was eliminated following administration of the trihydrate and 52% from the potassium salt. The entire difference between the two drug forms was accounted for in the initial 4 hr postadministration.

Several studies compared blood levels obtained with erythromycin and its salts and esters. Erythromycin estolate produced blood levels that were severalfold higher than those obtained with erythromycin base or erythromycin stearate (206-208). These differences were found to persist in the fasting as well as nonfasting subjects (207), indicating that food did not appreciably alter the absorption of erythromycin estolate when given under single or

multiple dosing (207). This finding is explained by the fact that this salt is acid stable and alkaline dissociable, permitting its passage through the acid of the stomach both in fasting and nonfasting subjects (209). Accordingly, the antibacterial activity remained essentially the same when this form of erythromycin was given, regardless of the state of fasting of the subject (209).

On first inspection, the higher serum levels attained with erythromycin estolate suggest that the salt form is more readily absorbed. Also critical to efficacy, however, is the volume of distribution of the drug, since extensive binding to plasma proteins can render a drug unavailable for activity at the biophase. Therefore, the significance of blood level data greatly depends on the measure of the free or unbound fraction of total antibiotics in the blood, which more directly indicates probable therapeutic benefit.

Wiegand and Chun (210) showed that, despite the higher blood levels attained with erythromycin estolate (after correction for half-life differences), the stearate salt produced seven times more free drug in serum than did the estolate salt. This finding explained the higher total tissue levels observed on administration of the stearate. They attributed the difference to a greater serum protein binding of the intact erythromycin estolate, proving that its higher serum levels did not necessarily reflect more efficient absorption.

Marked differences have been observed following oral administration of various salts of penicillin. Penicillin G potassium has been compared with penicillin G benzathine (benzethacil) (211, 212), penicillin G hydrabamine (213), penicillin V (214), penicillin G procaine (212), and penicillin G ammonium (215). As anticipated, penicillin G potassium produced higher and earlier blood levels than penicillin G benzathine (211, 212). Furthermore, tablets of penicillin G potassium buffered with sodium citrate yielded higher peak levels than unbuffered penicillin G potassium. While the absorption of buffered tablets was apparently not significantly affected by food intake, the unbuffered tablets yielded lower average levels and irregular absorption under similar conditions.

When penicillin G potassium was compared with penicillin G hydrabamine (213), a less soluble salt, blood levels similar to those produced by penicillin G benzathine were observed. When equivalent doses were administered, the penicilemia that occurred with penicillin G hydrabamine was only one-third or one-fourth as great and was of shorter duration than that produced by penicillin G potassium.

Budolfson *et al.* (212) found that peak concentrations of penicillin G potassium were three to four times those obtained with penicillin G procaine and five to six times those of penicillin G benzathine, indicating a more rapid rate of absorption. The therapeutic action was related to the maximum concentration attained, but it also depended on the persistence of penicilemia, which was greater with penicillin G potassium than with the other two compounds. The authors suggested that the lower blood levels attained with the relatively insoluble penicillin G benzathine were caused by its destruction in the GI tract prior to absorption. This suggestion seems unlikely, however, since the drug should not degrade very rapidly as an undissolved suspension.

Because of its superior stability in gastric juice, penicillin

V produces higher blood penicillin levels than corresponding doses of penicillin G. As a result, extensive investigations have been conducted with various salt penicillin V (99, 214-220). For instance, tablets, capsules and oral suspensions of penicillin V acid produced significantly higher blood concentrations than comparable penicillin G preparations (214). In the same study, average serum levels produced by the benzathine salt penicillin V were significantly higher than comparable doses of penicillin G benzathine for the first 4 hr but lower thereafter, again illustrating the value of using an insoluble salt to prolong blood levels of an acid-unstable compound. In another study (215), penicillin V acid was shown to produce higher and more prolonged plasma concentrations than either penicillin G potassium or ammonium, where properties were comparable.

Plasma levels were correlated with dissolution rate of various forms of penicillin V (99). As solid dosage for the readily soluble potassium and calcium salts produced earlier and higher blood levels in fasting subjects than the free acid or its benzathine salt. On the other hand, when the potassium and benzathine salts were administered orally as solutions, absorption was the same, implying that the poor solubility of the benzathine salt was responsible for the inferior blood levels obtained from solid dosage forms. Other studies found that, while potassium salt is 40% better absorbed than the free acid in fasting subjects, both forms produce therapeutic levels when administered with food (218).

Experiments with fistulated dogs indicated that penicillin V is absorbed primarily from the stomach. Therefore, it is not surprising that the potassium salt should exhibit higher blood levels on oral administration since it is the most soluble salt in gastric pH (216). In accordance with this observation, it was also reported that the benzathine salt exhibited higher serum levels in patients with gastric achlorhydria (pernicious anemia) than in patients with normal gastric function (219). Differences in gastric emptying time may also explain this result.

Several studies compared the absorption of tetracycline and its salts (103, 221, 222). For example, serum concentrations in dogs and humans showed that a phosphate complex salt of tetracycline was absorbed more rapidly and gave higher blood levels during the first 6-8 hr than tetracycline hydrochloride (221). The total amount of drug absorbed was about twice as great with the former compound.

Another study (222) suggested that tetracycline base produced higher blood levels than tetracycline hydrochloride. However, a subsequent investigation (223) showed that, in the absence of adjuvants or fillers, tetracycline hydrochloride and tetracycline base were absorbed equally well. Results obtained in this same study indicated that tetracycline hydrochloride encapsulated with citric acid produced higher serum concentrations than tetracycline hydrochloride mixed with hexametaphosphate or a phosphate complex salt of tetracycline.

In a study comparing urinary excretion rates and *in vitro* dissolution, the absorption of tetracycline and tetracycline phenolsulfonaphthaleinate was rate limited by their dissolution rates, whereas tetracycline hydrochloride absorption was rate limited by the absorption process itself (103).

20
17

Several lincomycin salts were studied for their comparative availability (224). In particular, the blood levels obtained with the relatively water-insoluble hexadecylsulfamate salt were compared to those of the hydrochloride following oral administration. Higher and extended whole blood and serum concentrations were obtained in mice, rats, and dogs with the hexadecylsulfamate. However, subcutaneously administered lincomycin did not produce significantly different fractions absorbed, regardless of which salt was administered. It is not known whether the greater area under the curve with oral administration of lincomycin hexadecylsulfamate is due to greater absorption from the GI tract, slower renal clearance, or greater enterohepatic circulations.

Salts of streptomycin, neomycin, viomycin, and streptothricin have been formed with: (a) polyacrylic acids; (b) sulfonic or phosphorylated polysaccharides, and (c) natural polycarboxyl acids from a series of polyuronic substances and polysaccharide derivatives containing carboxyl groups (18). The report indicated that these salts were absorbed from the injection locus primarily by the lymph system. Blood levels from the salts were generally lower but were maintained for a longer time than the equivalent amount of antibiotic alone, and higher concentrations of longer duration may actually be produced in the lymphatic drainage.

The influence of salt formation on the onset and duration of pharmacological activity also was illustrated with tolbutamide and several of its salts (101). Following oral administration, the sodium salt produced a rapid decrease in blood sugar level followed by a rapid recovery. By contrast, the free acid of tolbutamide caused a slow and prolonged drop in blood sugar level, a preferred effect since the chance of hypoglycemic shock would be lessened. This finding also illustrates the often overriding influence of the actual disease state on the choice of drug form.

Additional references on the implications of salt formation on absorption are listed in Table VIII.

Pharmacokinetics—Because of the various new properties that are usually imposed on a compound by salt formation, the pharmacokinetics of the drug necessarily change as a function of these properties.

For example, a pharmacokinetic evaluation comparing ampicillin sodium and potassium with ampicillin trihydrate was performed after oral administration to beagle dogs (243). The absorption rate constants of the sodium and potassium salts, which were similar, proved significantly greater than the rate constant of ampicillin trihydrate, resulting in earlier, higher peak concentrations with two to three times higher serum concentrations during the first hour. Yet, any differences between the fraction absorbed or the three products were not statistically significant. Apparently, although dissolution of the ampicillin trihydrate was the rate-limiting step in its absorption, the overall extent of bioavailability remained unaffected.

An interesting study of the biliary excretion of erythromycin base and erythromycin estolate was reported (244). The biliary excretion of erythromycin base was high, while that of erythromycin estolate was much lower; referential secretion of erythromycin in the bile could partially account for the lower serum levels exhibited by the base. However, the proportion of the ingested dose excreted in the bile was small, and the total amounts in-

Table VIII—Additional References on Bioavailability and Absorption Alteration

Topic	Reference
Blood levels produced by three theophylline-containing elixirs	226
Naproxen oral absorption characteristics	226
Effect of food on absorption of a new form of erythromycin propionate	227
Effect of the anion on the absorption of tetracycline from the rat stomach	186
Blood levels following oral administration of different preparations of neobiotin	228
Absorption of isopropyl acid and its sodium salt	230
Oral absorption of secobarbital (quinabarbital) and its sodium salt	230
Absorption rate of barbiturates in humans	231
Morphine and atropine mucate	232
Excretion of buprenorphine salts in urine of human volunteers	233
Polymethylene bis(isothiazonium) salts: antituberculous activity	234
Prolonged antitussive action of a resin-bound noscapine preparation	235
Pharmacology of sulfapyridine and sulfathiazole	236
Evaluation of plasma concentrations of propoxyphene utilizing a hybrid principal component analysis of variance technique: equimolar doses	237
Antrycide, a new trypanocidal drug	238
Pralidoxime methanesulfonate: plasma levels and pharmacokinetics after oral administration to humans	239
Intestinal absorption of pralidoxime and other aldoximes	240
Blood plasma levels and elimination of salts of pralidoxime (2-PAM) in humans after oral administration	241
Enhancement of GI absorption of a quaternary ammonium compound by trichloroacetate	242

involved were not sufficient to account entirely for the differences in serum concentrations attained. Undoubtedly, the protein binding studies of Wiegand and Chun (210) (discussed under *Absorption Alteration*) more satisfactorily explain the difference in serum concentrations.

Often, salt formation can be used to modify drug absorption and dose tolerance favorably. For example, aminosalicylic acid exhibits a short half-life and, therefore, requires large and frequent doses which may cause gastric irritation. Consequently, different chemical forms such as salts have been prepared (119, 245-247) to reduce the incidence of gastric irritation, increase absorption, and prolong blood levels.

Aminosalicylic acid is an interesting example in other ways; considerable confusion about this drug exists because many fail to recognize its nonlinear pharmacokinetics. Several definitive studies were reported regarding the absorption of the acid and its sodium, potassium, and calcium salts from solution, suspension, and tablet formulations (245, 246). Comparison of the relative bioavailabilities of aminosalicylic acid suspended in water and its salts dissolved in water showed that, while differences in rate of absorption were found to exist, absorption of both the acid and its salts was essentially complete. Absorption of the free acid from tablets reached only 77% of the dose, whereas that of the tableted salts was rapid and complete.

Regardless of formulation, the area under the plasma concentration-time curve of unmetabolized drug from free acid administration was less than that for the salts. This result was attributed to concentration-dependent metabolism during absorption: when the rate of absorption is high, the metabolic processes become saturated and more unmetabolized drug remains in the blood; conversely,

Table IX—Additional References on Bioavailability and Pharmacokinetics

Topic	Reference
Pharmacodynamics of fosfomycin (phosphonomycin) after intravenous administration to humans	248
Pharmacodynamics of phosphonomycin after oral administration to humans	249
Comparative studies on distribution, excretion, and metabolism of ³ H-hydroxyzine and its ¹⁴ C-methiodide in rats	250
Pharmacokinetics of ampicillin trihydrate, ampicillin sodium, and dicloxacillin sodium following intramuscular injection	251
Physiological disposition of fenopfen in humans: pharmacokinetic comparison of calcium and sodium salts administered orally	252

when the absorption rate is low, as for the free acid, a higher percentage of drug is metabolized.

Additional references regarding bioavailability and pharmacokinetics are presented in Table IX.

GENERAL PHARMACY

Pharmacological Effect.—Chlorpromazine hydrochloride and quaternary chlorpromazine chloride were investigated with respect to their effects on the central nervous system (CNS) (253). The quaternized compound was less potent and more toxic in rodents than the parent tertiary compound.

Naloxone, an effective opiate antagonist, is generally used as the hydrochloride salt; however, the drug has a very short duration of action. The mucate salt was prepared to extend its duration of action, since mucic acid is only slightly soluble in water (254). In a test on the blocking of morphine activity in mice, however, the mucate salt did not differ in duration from the hydrochloride. These investigators assumed the same receptor site for naloxone as for morphine and, since Heron's (232) work suggested that the receptor had a greater affinity for morphine mucate than for the free base, it also should have a greater affinity for naloxone mucate. The results disproved this hypothesis. Furthermore, this theory implies that intact salt reaches the receptor, which is highly unlikely, regardless of whether the drug is administered as a solution or as a suspension.

A series of salts of 9-aminoacridine and its derivatives was prepared and screened for antifungal and antibacterial activity (255-257). By using salts of fatty acids, the antifungal action was found to parallel the length of the carbon chain of the anion, with maximal activity occurring with acridine caproate, undecylate, and undecylenate (where undecylanic acid also exhibits some intrinsic antifungal activity) (255). This result appears reasonable, because these salts would be more lipid soluble and could be expected to pass through the cell wall of the infecting organism more readily, probably as an ion-pair.

The efficacy of bases or salts as topical anesthetics for relieving cutaneous itch, burning, and pain in unbroken skin has also been examined (258). In these experiments, itching and pricking were induced by an alternating current of low amperage and voltage applied to the skin or by exposure of the skin to UV light. Interestingly, aqueous solutions of salts of the local anesthetics did not alleviate itching or burning in any of the subjects, although saturated solutions of their bases in a mixture of water, 40%

Table X—Additional References on General Pharmacy and Pharmacological Effect

Topic	Reference
Differential excretion of bromide and chloride ions and its role in bromide retention	259
Pharmacological study of calcium methionate. Synthesis and <i>in vitro</i> fungistatic evaluation of some N-substituted amides and amine salts of sorbic acid	260 261
Antimicrobial studies on clameoxyquin [5-chloro-7-[(3-diethylaminopropyl)amino]methyl]-8-quinolinol] <i>in vitro</i> and in experimentally infected animals	262
Adjunctive value of oral prophylaxis with the oximes pralidoxime (2-PAM) lactate and pralidoxime methanesulfonate to therapeutic administration of atropine in dogs poisoned by inhaled sarin vapor	263
Pralidoxime (2-hydroxyiminomethyl-N-methylpyridinium) methanesulfonate and atropine in the treatment of severe organophosphate poisoning	264
Efficacy and limitations of oxime-atropine treatment of organophosphorus anticholinesterase poisoning	265
Antitussive activity of enoxolone (glycyrrhetic acid) and its derivatives	266
Pharmacological properties of glycyrrhetic acid hydrogen succinate (disodium salt)	267
Ganglionic blocking activity of diastereomeric dimethylaminobornyl acetates and their methiodides	268
A new potent nonnarcotic antitussive, 1-methyl-3-bis(2-thienyl)methylene)piperidine: pharmacology and clinical efficacy	269

alcohol, and 10% glycerol were claimed to be effective. Such transport phenomena across the stratum corneum are often dependent on the polarity of the drug and vehicle and on the binding of the drug to keratin.

Additional references on pharmacological effects can be found in Table X.

Dialysis.—Dialysis through a cellophane membrane of the hydrochloride or sodium salts has been studied with several drugs (270). In many cases, it appeared that the ionic form of the drug was bound to the membrane whereas the nonionized form was not. Ephedrine hydrochloride presented an interesting example, however, since it dialyzed considerably faster than its corresponding base. It was theorized that the chloride ion dialyzed rapidly, enhancing the rate of dialysis of the ephedrine ion. Accordingly, when chloride ion was present on both sides of the membrane, the observed rate of dialysis for the ephedrine ion was comparable to the ephedrine base.

The diffusion of sodium chloride through a lipoprotein interface was very slow, especially if calcium chloride was present on both sides of the interface (271). In the presence of low concentrations of choline chloride or carbamylcholine chloride, the diffusion of sodium chloride is more rapid. Apparently, choline salts are able to increase the permeability of the lipoprotein to salts, which may relate to the physiological action of choline salts.

Miscellaneous.—Release rates were determined for aminophylline, ephedrine alkaloid, and ephedrine hydrochloride from theobroma oil suppositories containing nonionic surfactants (133). While surfactants with hydrophilic-lipophilic balance (HLB) values less than 11 only minimally affected release rate, rates increased with surfactants of HLB values greater than 11. Under optimal conditions, aminophylline was faster than ephedrine hydrochloride which, in turn, was superior to the ephedrine base.

Willis and Banker (272) reported on the formation of polymer-drug salts as an approach to the physicochemical design of dosage forms. Poly(methyl vinyl ether/maleic

anhydride) salts of methapyrilene were prepared and tested with the free base for *in vitro* dissolution and dialysis. Their dissolution and dialysis rates were not appreciably different from the free drug or its hydrochloride salt. Various poly(methyl vinyl ether/maleic anhydride) hemiester salts of methapyrilene exhibited substantially slower release than the polymer ether salts, hydrochloride salt, or free base forms. Polymer-drug salts thus appear to have promise.

A series of metallic salts of edetic (ethylenediaminetetraacetic) acid were tested *in vitro* to determine their effect on blood coagulation (273). The results showed that only the dipotassium and disodium salts had any effect on coagulation. It was theorized that the lack of anticoagulant activity resulted from an almost complete suppression of ionization of the heavy metal salts.

Interesting research regarding the angina-preventive effect of some chromone-2-carboxylate salts showed a direct correlation between biological activity and pKa of the salt-forming amines (274).

Lin *et al.* (112) investigated the relationship between salt form and biological activity of a given antihypertensive. While the intrinsic dissolution rates of the dihydrochloride and disulfate salts were many fold greater than monohydrochloride, the hypotensive potencies of the salts did not differ significantly from one another in an anesthetized dog study. Yet, when administered to renal hypertensive dogs, the dihydrochloride and disulfate salts produced greater hypotensive effects than did the monohydrochloride.

TOXICOLOGICAL CONSIDERATIONS

Toxicity of Salt Ion—Any discussion regarding the toxicity of salts of a drug must consider the pharmacological properties of the cation or anion used to form the salt as well as those of the free drug, since any of these may produce toxic effects. The toxicology of several ions that are commonly used to form salts and that are relevant to this review were discussed in depth (275).

Toxicity from ingestion of calcium salts of drugs is rare. If hypercalcemia occurs, however, calcium deposits in the kidney can bring on a reduction of renal function. The principal toxic effects of lithium also involve the kidneys. When small amounts of lithium are taken, no apparent toxicity occurs; yet large amounts of the metal can lead to irreversible damage. An apparent correlation was observed between lithium dosage and sodium intake (276). When lithium dosage was low or sodium intake was high, rats were able to excrete all lithium given and sustained a reversible polyuria. Conversely, if large amounts of lithium were administered to the rats or if their sodium intake was lowered, they incurred irreversible kidney damage. Ammonium ion, although it serves a major role in maintenance of the acid-base balance of the body, can be toxic in high concentrations and initiate CNS derangements.

Sulfate ions given orally tend to be minimally absorbed and may act as a laxative. The nitrate ion is irritating to the GI tract, causing nausea and gastric distress. Also, intestinal bacteria may convert the nitrate ion to nitrite which oxidizes hemoglobin to methemoglobin. The citrate ion, an intermediary in carbohydrate metabolism, can form a soluble complex with calcium which is poorly dissociable

and rarely causes any toxic reactions. While tartrate ions are usually absorbed minimally from the GI tract, high concentrations reaching the circulation can cause renal damage.

Acetate and lactate ions are normal metabolites and appear to be well tolerated in relatively large amounts. Iodide and bromide ions can produce conditions known as iodism and bromidism, respectively. Bromide intoxication occurs quite frequently, since bromides are used as ingredients in some nonprescription preparations (277-280). Bromide is slowly excreted by the kidney (its half-life is 12 days) and tends to accumulate when taken for prolonged periods or when used by patients with decreased renal function (277).

Toxicity of Salt Form—Provided the salt-forming agents are nontoxic, the relative toxicities of a series of salts of a compound are often observed to reflect directly their absorption rates. For example, the toxicities of dibromide, dichloride, diiodide, and dimethylsulfate salts of quinapyramine³, a trypanocidal drug, were determined (238). The sparingly soluble halogen salts were much less toxic subcutaneously or intramuscularly than the freely soluble dimethylsulfate, yet all salts showed about equal toxicity upon intravenous administration. The difference in toxicities obviously resulted from rapid absorption of the methylsulfate compared to the slowly absorbed, poorly soluble halogen salts. Similar reasoning has been used to explain the acute oral toxicity of propoxyphene hydrochloride in rodents, which is twice that of equimolar doses of the napsylate salt (281).

Several salts of benzphetamine and etryptamine were prepared as potential sustained-release formulations (114). The water solubility, *in vitro* dissolution rates at pH 1.0 and 7.2, and the median lethal times (LT₅₀) were determined for each salt. Both the LT₅₀ and LD₅₀ (determined on only a few salts) increased as the *in vitro* dissolution rate at pH 7.2 decreased. While dissolution at pH 1.0 did not correlate well with toxicity, the LT₅₀'s were inversely related to the square root of the dissolution rates at pH 7.2.

Toxicity studies comparing iopanoic acid, a cholecystographic contrast medium, with its sodium salt (115) showed that the salt form has 10-fold greater toxicity. The LD₅₀'s of the free acid and the salt were 22 and 2.32 g/kg, respectively. It was postulated that the free acid precipitated from the sodium salt upon its reaction with gastric hydrochloric acid. The fine, amorphous particles of precipitated acid had a greatly increased surface area and, therefore, dissolved more rapidly than even fine crystals of the free acid. The faster and more complete drug absorption then resulted in increased toxicity.

Salts exhibiting greater water solubility than their parent compounds or less soluble salts are not always more toxic. For example, various inorganic and organic ions were used to prepare salts of methyl pyridinium-2-aldoxime that would have greater water solubility and would eliminate undesirable side effects due to the iodide ion (95). Even though the aqueous solubility of the majority of these salts was many times greater than the iodide, their toxicity on a molar basis was not significantly different, with the exception of the dihydrogen phosphate salt which was 15%

³ Aniracydia.

Table XI—Additional References on Toxicological Considerations

Topic	Reference
Toxicity and absorption of 2-sulfanilimidopyridine and its soluble sodium salt	285
Sorbic acid as a fungistatic agent for foods: harmlessness of sorbic acid as a dietary component	286
Toxicity and distribution of erythromycin	287
Further toxicological studies with erythromycin	288
Pharmacology and toxicology of erythromycin estolate	289
Erythromycin propionate (propionylerythromycin): a review of 20,525 case reports for side-effect data	290
New class of antibiotic salts of reduced toxicity	22
GI intolerance to oral iron preparations	291
Comparative toxicology of iron compounds	292
Influence of the dissolution rate of lithium tablets on side effect	123
Toxicity and tissue distribution studies on the hydrochloride, bismuth iodide complex, and a resinate of emetine	293
Becitracin zinc in pharmaceutical preparations	145
New approach to quaternary ammonium compounds	151
Pharmacology of choline theophyllinate	294

more toxic. Further research with oximes revealed that other salts are also toxic (282).

GI bleeding is a common toxic effect of aspirin for a large percentage of the population. Consequently, a search was initiated for an aspirin derivative that would not induce GI blood loss (283). All compounds prepared, however, including the sodium and calcium salts, caused GI hemorrhage with a severity similar to aspirin.

Polyene antibiotics are potent antifungal agents but bear considerable toxicity. Even though the methyl ester hydrochlorides of these compounds are more soluble, they retain almost all of their antifungal activity and, more significantly, show a uniform decrease in toxicity compared to their parent compounds (284).

Additional references on toxicological considerations of salt formation are given in Table XI.

CONCLUSIONS

Salt formation is a means of altering the physical, chemical, and biological characteristics of a drug without modifying its chemical structure. Clearly, the salt form can have a dramatic influence on the overall properties of the parent compound. At present, selecting a salt form that exhibits the desired combination of properties is a difficult semilempirical choice. Pharmaceutical scientists now recognize these facts and are beginning to study the effects of different salt forms on the physicochemical properties, bioavailability, and toxicity of drug substances.

Although now only a few generalizations are available to predict the effect of particular salt forms on the characteristics of a drug, perhaps in time it will be possible to evolve increasingly more powerful generalizations regarding the effect of a salt on the properties of its parent compound. In addition, we predict that polymer-drug salts will have a revolutionary effect on future trends in drug therapy, particularly in the areas of reducing drug toxicity and in controlling the release profile of novel drug delivery systems.

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