Ruthenium Melt Catalysis

PRODUCING CHEMICALS FROM SYNTHESIS GAS

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A range of commodity chemicals and fuels can be generated directly from synthesis gas by ruthenium melt catalysis. Careful selection of the catalyst components enables a wide range of oxygenates to be produced, while other advantages of this flexible process include high productivity and the ease with which the products may be recovered and the catalyst recycled.

In platinum-metal catalysed organic synthesis, the primary purpose is to produce pure products in high yields, with good reproducibility and ease of product isolation. While both homogeneous and heterogeneous catalysis systems may fulfill these roles in laboratory or industrial processes, an alternative approach, that has many of the inherent advantages of both systems, is the use of molten salts as catalyst and/or reaction media.

Molten salts may be classified into simple ionic salts (for example the alkali and alkaline earth metal halides), simple and polymeric oxyanionic salts (such as metal nitrates, carbonates, phosphates, borates), and salts containing organic cations and/or anions (including the quaternary phosphonium and ammonium salts) (1). The high thermal stability of many of these melts, together with their low vapour pressure, good thermal and electrical conductivity, and low viscosity provides them with a range of important physical and chemical advantages over conventional homogeneous and heterogeneous catalyst systems (2). Molten salts, such as the quaternary phosphonium salts, dissolve a broad range of metals, oxides and complexes; high reaction rates and yields are often possible (for example organic syntheses in molten tetrachloroaluminate solvents (3) and fused alkali metal salts (4)) with ease of product/catalyst separation and recovery. Where chemical synthesis occurs at a melt-gas interface, as in gas reactions, the ability to present a renewable surface may avoid many of the problems of deactivation seen with conventional heterogeneous catalysts (4).

Frequently, the melt is called upon to play more than one role in a chemical process. It may, for example, simply act as a solvent for reactants and products; it may be a catalyst; it may supply one or more of the reactants, as well as aid in controlling the heat of reaction. The salts may be used singly (for example molten Na_2CO_3, $ZnCl_2$ or $AlCl_3$), or as eutectic mixtures (such as Li_2CO_3-Na_2CO_3-K_2CO_3, $CuCl$-$CuCl_2$-KCl, and $AlCl_3$-BuPyCl) where the lower liquidus temperatures may be advantageous.

Molten salts have already found numerous technical applications in industrial catalytic processes. Examples include the Transcat, Deacon and SO_2 oxidation processes (1,2). The literature illustrating the diverse uses of melt catalysis with the platinum group metals includes applications in chlorination (2), oxidation (5) and selective hydrogenation (6) processing, as in Equation i:

$$\text{Equation i: } \xrightarrow[\text{H}_2]{\text{PtCl}_2\text{-Et}_4\text{NSnCl}_3} \qquad i$$
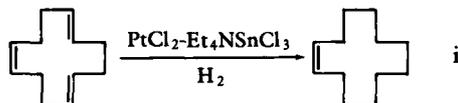
In the case of synthesis gas (carbon monoxide/hydrogen) chemistry, Fischer-Tropsch production using $Ir_4(CO)_{12}$ dissolved in $NaCl$-$AlCl_3$ melts has now been demonstrated (7); ethane is the major product fraction,

see Equation ii or, under flow conditions, isobutane and propane. A further examination, by Collman and his colleagues, implicates chloromethane (or methanol) as the primary intermediate, with methane, ethane, and chloromethane the major carbon-containing products (8).

$$CO + 3H_2 \longrightarrow C_2H_6 \text{ (major)} + CH_4 +$$
$$C_3H_8 \text{ (tr)} + C_4H_{10} \text{ (tr)} \quad \text{ii}$$
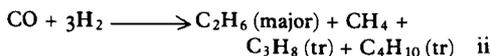
Ruthenium Melt Catalysis

In other, potentially far-reaching applications of melt catalysis by the platinum group metals, we at Texaco have demonstrated the synthesis of a range of commodity chemicals and fuels directly from synthesis gas by the use of ruthenium-containing molten salt catalysis. Products include ethylene glycol, C_1–C_4 alcohols, acetic acid, acetate esters, C_2+ olefins and vicinal glycol esters. In its simplest form, this new class of melt catalyst comprises one or more ruthenium sources, including ruthenium carbonyls, oxides and complexes dispersed in a low-melting (m.p. <150°C) quarternary phosphonium or ammonium salt, for example tetrabutylphosphonium bromide. The key components are selected such that:

[A] The catalyst mix is a solid under ambient conditions.

[B] The quarternary salt melts below the temperatures of carbon monoxide hydrogenation so that, under typical operating conditions, it is a highly polar, non-volatile, liquid media that readily solubilises the ruthenium catalyst precursor and the synthesis gas components, thereby ensuring rapid rates of carbon monoxide hydrogenation to the desired aliphatic oxygenates.

[C] Optionally, upon cooling, the ruthenium-quarternary salt may resolidify, allowing ease of separation of the liquid organic products from the solid inorganic catalyst components by decantation or distillation.

The melt catalyst enjoys, thereby, certain of the intrinsic advantages of both homogeneous and heterogeneous systems; the inherent high selectivity and reproducibility of liquid homogeneous catalysts under normal carbon monoxide hydrogenation conditions, and the ease of product-catalyst separation, typical of heterogeneous catalyst systems, once the reaction is complete.
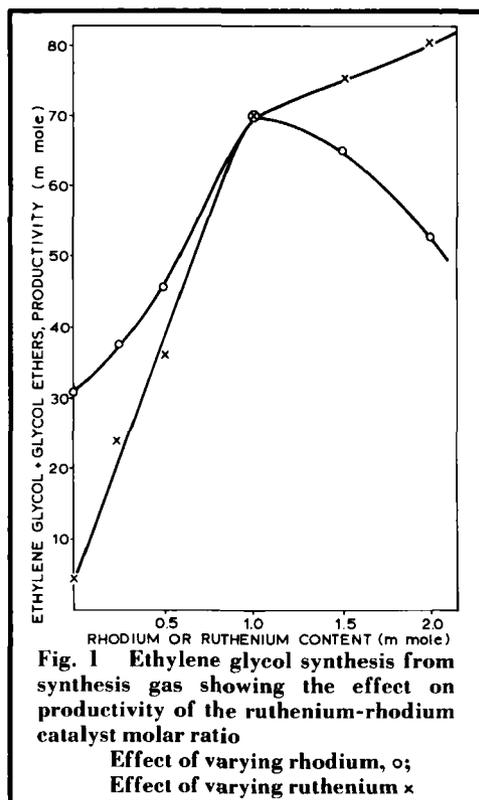
Optionally, a second or third transition metal may be added to the ruthenium to further modify its performance and to steer the product distribution toward specific aliphatic oxygenates. These modifiers may be derivatives of rhodium, cobalt, manganese, rhenium, zirconium and titanium, in either halogen-free or halogen-containing forms.

Some specific applications of this technology include (Equations iii to viii):

[1] Ethylene glycol synthesis directly from synthesis gas using ruthenium-rhodium catalysts or ruthenium alone (9).
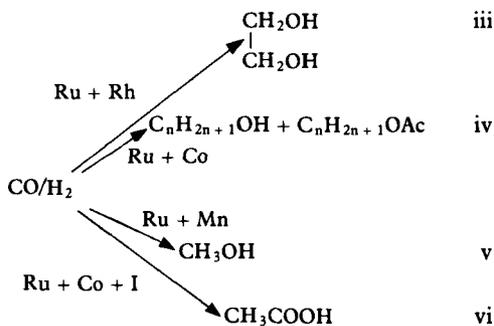
[2] C_1–C_4 Alcohol/acetate ester fuel products, which are potential octane enhancers, using ruthenium in combination with cobalt, titanium or zirconium (10).

[3] Selective methanol production with the

Fig. 1 Ethylene glycol synthesis from synthesis gas showing the effect on productivity of the ruthenium-rhodium catalyst molar ratio
Effect of varying rhodium, o;
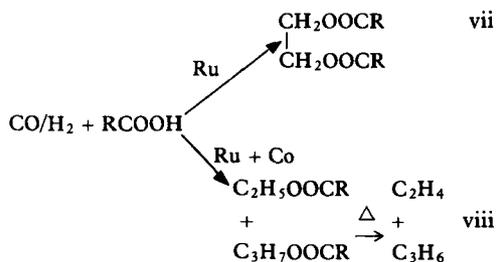Effect of varying ruthenium ×

ruthenium-manganese combination (10, 11).

[4] Acetic acid production directly from synthesis gas catalysed by halogen-promoted ruthenium-cobalt combinations (11).

$$CO/H_2 \begin{cases} \overset{Ru + Rh}{\nearrow} & \overset{CH_2OH}{\underset{|}{CH_2OH}} \quad \text{iii} \\ \overset{Ru + Co}{\searrow} & C_nH_{2n+1}OH + C_nH_{2n+1}OAc \quad \text{iv} \\ \overset{Ru + Mn}{\searrow} & CH_3OH \quad \text{v} \\ \overset{Ru + Co + I}{\searrow} & CH_3COOH \quad \text{vi} \end{cases}$$

Through the addition of aliphatic carboxylic acid coreactants, this chemistry may be further extended to:

[5] The production of vicinal glycol esters (Equation vii) (12).

[6] The generation of ethylene and propylene from synthesis gas (13) by a novel two-step procedure involving the intermediate generation of ethyl and propyl esters (Equation viii).

$$CO/H_2 + RCOOH \begin{cases} \overset{Ru}{\nearrow} & \overset{CH_2OOCR}{\underset{|}{CH_2OOCR}} \quad \text{vii} \\ \overset{Ru + Co}{\searrow} & \begin{matrix} C_2H_5OOCR \\ + \\ C_3H_7OOCR \end{matrix} \overset{\triangle}{\underset{\rightarrow}{}} \begin{matrix} C_2H_4 \\ + \\ C_3H_6 \end{matrix} \quad \text{viii} \end{cases}$$

Ethylene Glycol

Ethylene glycol commands a 4.5×10^9 lb/yr market in the United States of America, and while this large-volume petrochemical is presently generated entirely by ethylene oxide hydrolysis, there has been considerable research activity during the past decade into alternate routes to polyhydric alcohols either directly, or indirectly, from synthesis gas. We have demonstrated the preparation of ethylene glycol and its monoalkyl ether derivatives from synthesis gas (Equation iii) using ruthenium or a ruthenium-rhodium catalyst combination dispersed in a low-melting quaternary phosphonium salt such as tetrabutylphosphonium bromide. The advantages of the mixed ruthenium-rhodium system include improved glycol productivity and ability to operate at lower synthesis gas pressures. It may be noted that (see Table I):

(1) The productivity of the ruthenium-rhodium melt catalyst is high; liquid weight gains may exceed 200 weight per cent (expt. 2) and turnover frequencies surpass 5×10^{-3}/s at 220°C.

(2) Glycol:alkanol weight ratios of 1:1.37 have been realised (expt. 6).

(3) Both alkanol and diol products may be readily isolated by fractional distillation of the crude liquid product and the solid residual ruthenium-rhodium catalyst recycled.

The primary requirements in selecting the quaternary Group VB salts (Table I) as suitable reaction media are that they be thermally stable under typical carbon monoxide hydrogenation conditions and that they melt below the reaction temperature (200 to 250°C) to give stable, highly polar, fluid media for solubilisation of the transition-metal component.

Figure 1 illustrates how both the ruthenium and rhodium catalyst components are beneficial to the formation of ethylene glycol, expressed here in terms of total glycol + glycol ether productivity, for the $Ru(acac)_3$-$Rh(acac)_3$/ Bu_4PBr catalyst precursor. Maximum glycol production is achieved with increasing rhodium addition, up to rhodium:ruthenium ratios of about 1:1. Very little diol is generated, however, in the absence of either the ruthenium component (see Figure 1), or the quaternary phosphonium salt (Table I, expt. 5). While the presence of ruthenium is necessary to the formation of glycol, the data of Figure 1, together with the isolation of mixed ruthenium-rhodium clusters such as $Ru_2Rh(CO)_{12}$ (9), point to the role of the second metal, rhodium, in providing improved diol selectivity.

Alcohol-Ester Fuels

A second class of platinum metal melt catalysts—comprising a ruthenium source, such as $Ru_3(CO)_{12}$, optionally in combination with a halogen-free cobalt, titanium, zirconium, manganese or rhenium component, dispersed

Table I

Ethylene Glycol from Synthesis Gas via Ruthenium-Rhodium "Melt" Catalysis[a]

Expt.	Ruthenium-rhodium source	Quaternary salt	Melting point,[b] °C	Product yield, mmole				Total liquid yield, weight per cent[d]
				CH_2OH–CH_2OH	CH_2OH–CH_2OR[c]	MeOH	EtOH	
1	$Ru(acac)_3$–$Rh(acac)_3$	Bu_4PBr	100	77.2	62.6	250	168	189
2	,,	Bu_4PI	96	80.4	41.6	312	237	214
3	,,	$C_{16}H_{33}Bu_3PBr$	54	11.4	42.8	295	228	176
4	,,	$C_7H_{15}Ph_3PBr$	179	0.5	0.4	0.1	0.7	<3
5	,,	None	—	0.2	—	8.9	0.9	e
6	,,	Bu_4PBr	100[f]	30.3	14.3	96	23	57

[a] Charge: ruthenium 4.0 mmole; rhodium 2.0 mmole; R_4PX 15g; run conditions: 220°C; 430 atm constant pressure; CO/H_2 (1 : 1); 6–18 hr.
[b] Melting point of quaternary salt must be substantially below the reaction temperature (220°C).
[c] Ethylene glycol monoalkyl ether, $HOCH_2CH_2OR$; R = Me, Et.
[d] Liquid yield (wt %) calculated basis total weight of catalyst + quaternary salt charged.
[e] Product liquid is > 90% water.
[f] Run time, 2 hr.

in a quaternary phosphonium salt—has been found to be effective for the selective synthesis of (a) methanol, (b) ethanol and (c) their acetate esters directly from synthesis gas (see Table II). These liquid products are intended for use as octane enhancers for gasoline. The shift to unleaded and low-leaded gasoline in both the United States and Europe will likely raise the clear octane requirements by about two octane numbers. Although some of this increase could be satisfied by higher severity processing, octane improvers, particularly liquid aliphatic oxygenates, are becoming an increasingly attractive alternative.

Here it may be seen from an inspection of the summary data in Table II that:

(1) Ethanol may constitute near 60 per cent of the crude liquid product with 76 per cent being C_1–C_3 alcohol, when employing the RuO_2-Bu_4PI couple (expt. 7). The ruthenium/halide-free titanium/Bu_4PBr combination likewise produces C_1–C_3 alcohols in 61 per cent selectivity of which up to 66 per cent is ethanol (expts. 10 and 11).

(2) A balanced mix of C_1–C_3 alcohol and acetate esters may be realised in high yields using a variety of ruthenium-cobalt bimetallic catalysts as illustrated here by expts. 8 and 9.

(3) Methanol will be the predominant product fraction when the melt comprises ruthenium plus a halogen-free manganese or rhenium component. With RuO_2-$Re_2(CO)_{10}$/Bu_4PBr (expt. 12), methanol selectivity in the liquid product is 85 per cent and the turnover frequency is 24 mol MeOH/g atom ruthenium/hr.

(4) The addition of certain solvents may lead to further changes in product composition. The presence of added p-dioxane, for example (expt. 14), makes ethyl acetate the predominant product, with alkyl acetates providing 67 per cent of the organic liquid fraction.

Numerous factors must, of course, be considered in the selection of organic oxygenates as blending components in gasoline, particularly cost, octane blending value, volatility, water and gasoline compatibility, raw material availability, engine performance and corrosion,

as well as environmental problems (10). In our work, we have focused on two C_1–C_3 alcohol/ester blends produced by carbon monoxide hydrogenation (Equation iv) using the Texaco melt technology. The first blend (see Table III, product mix "A"), rich in methanol and ethanol, is similar in composition to those prepared by the procedure of Table II, expt. 7. The second blend ("B") contains sizeable quantities of methyl and ethyl acetates, and more closely resembles the products of Table II, expt. 9, generated using a ruthenium-cobalt couple. Both blends are, of course, the products of numerous runs under standard operating conditions; they have been isolated with the minimum of fractionation.

Preliminary performance data for the two blends indicates:

(a) The octane improvement properties of the C_1–C_3 alcohol mix, "A", appear to be good, and on this basis it may show promise as a future octane blending agent. The improvements in motor octane number (ΔMON) and research octane number (ΔRON) values, about 1.4 and 3.4, respectively, for mix "A", are noticeably higher than those for composite alcohol-ester mix, "B", but the increase in volatility is greater for the alcohol/ester gasoline blend (14).

(b) The oxidative stability and gum-forming tendencies of the gasoline-containing alcohol/ester mix appear poorer than for gasoline containing mix "A". Stability of mix "A" is equivalent to that of gasoline (14).

(c) The alcohol composition in gasoline exhibits superior corrosion properties, when compared to "B" blend, for each of the metals commonly used in automotive engine surfaces.

Acetic Acid

Acetic acid is another commodity chemical with a large market requirement, of about 2.9×10^9 lb/yr in the U.S., that has been targeted as being potentially made directly from synthesis gas (Equation vi) (15), rather than by methanol carbonylation or through oxidation chemistry. We have established that acetic acid may be generated directly from synthesis gas as

Table II

Alkanols Plus Acetate Esters from Synthesis Gas[a]

| Expt. | Catalyst precursor | Quaternary salt | Melting point °C | Liquid product composition, weight per cent[c] | | | | | | Liquid yield, per cent |
| | | | | Alcohols | | | Acetate esters | | | |
				MeOH	EtOH	PrOH	MeOAc	EtOAc	PrOAc[b]	
7	RuO_2	Bu_4PI	96	12.9	59.5	3.7	3.3	6.4	0.6	151
8	RuO_2-$Co(acac)_3$[d]	Bu_4PBr	100	10.2	28.2	13.7	5.9	19.9	9.5	215
9	$Ru_3(CO)_{12}$-$Co_2(CO)_8$[d]	Bu_4PBr	100	9.3	29.1	12.6	7.0	21.1	11.9	230
10	RuO_2-$Ti(acac)_2(OBu)_2$	Bu_4PBr	100	16.3	40.7	4.3	3.5	8.0	4.3	169
11	RuO_2-$Ti(OMe)_4$	Bu_4PBr	100	21.0	39.0	5.4	3.6	6.1	3.1	239
12	RuO_2-$2Re_2(CO)_{10}$	Bu_4PBr	100	84.7	9.4		0.4	0.3		85
13	RuO_2-$8MnCO_3$	Bu_4PBr	100	86.3	2.3		1.3	0.5		85
14	RuO_2-$\frac{1}{4}Co_2(CO)_8$[e]	$C_7H_{15}Ph_3PBr$	179	<1	4.0	<1	7.0	54.0	6.0	

Table III
Alcohol/Ester Fuels from Synthesis Gas

Component	Volume per cent	
	Product mix "A" C_1-C_3 alcohols	Product mix "B" C_1-C_3 alcohol/esters
Methanol	46.6	30.3
Ethanol	40.4	22.1
iso-Propanol	—	1.0
n-Propanol	1.4	2.2
n-Butanol	—	3.5
n-Pentanol	—	1.9
Methyl acetate	0.7	13.4
Ethyl acetate	2.3	15.5[b]
Propyl acetate	—	10.1[b]
Higher oxygenates	8.6[a]	—
	100.0	100.0

[a] Includes: 1,3-dioxolane and its alkyl derivatives, alkoxymethanes, alkoxyethanes, alkyl formates and alkyl propionates.
[b] Includes some alkyl propionates, substituted dioxolanes, mono and dialkoxyethanes, and dialkoxymethanes.

the predominant oxygenate product in 68 weight per cent selectivity (11) using $Ru_3(CO)_{12}$–$Co_2(CO)_8$/Bu$_4$PBr melt catalyst, preferentially where the cobalt:ruthenium and carbon monoxide:hydrogen ratios exceed unity (for example see Figure 2).

Short-Chain Fatty Acids

Platinum group metals dispersed as melt catalysts have also been utilised by Texaco in a novel process for making short-chain (C_5-C_{10}) fatty acids (SFAs). Now generated from coconut oil and through oxo chemistry, these SFAs find expanding applications in the synthetic lubricant and plasticiser markets.

We have demonstrated that ligand-stabilised palladium and platinum salts dispersed in quaternary Group VB salts of trichlorostannate(II) are effective catalysts for SFA

manufacture by the regioselective carbonylation of α-olefins (Eq. ix). Preferred catalyst formulations include bis(triphenylphosphine)-palladium(II) chloride and its para-tolyl analogue, $PdCl_2[(p\text{-}CH_3.X_6H_4)_3]_2$, dispersed in tetraethylammonium trichlorostannate(II). In the case of nonanoate ester synthesis, yields consistently exceed 80 mole per cent for both systems (16), and carboxylic acid linearity is greater than 80 per cent. A variety of alkene and alkyne structures may be carbonylated in the presence of different alkanol coreactants (see Table IV).

$$RCH = CH_2 + CO + R'OH \longrightarrow$$
$$R\text{-}CH_2\text{-}CH_2\text{-}COOR' \quad \text{ix}$$
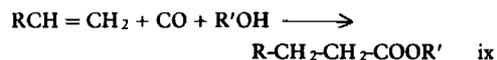
The palladium catalyst, $PdCl_2[P(C_6H_5)_3]_2$-10[($C_2H_5)_4$N][SnCl$_3$], exists under carbonylation conditions (Table IV) as a clear, homogeneous, phase with the α-olefin and

Table IV

Alkene/Alkyne Carbonylation Catalysed by PdCl$_2$[P(C$_6$H$_5$)$_3$]$_2$-10[(C$_2$H$_5$)$_4$N][SnCl$_3$]^a

Expt.	Alkene/alkyne	Alkanol	Conversion mole per cent	Identity	Selectivity, per cent[b]	Yield. mole per cent
17	1-Hexene	Ethanol	51	Ethyl heptanoate	79.2	51
18	1-Octene	Ethanol	84	Ethyl nonanoate	86.3	62
19	1-Tetradecene	Ethanol	86	Ethyl pentadecanoate	90.9	64
20	3,3-Dimethyl-1-butene	Ethanol	40	Ethyl 4,4-dimethylpentanoate	99.5	36
21	2,4,4-Trimethyl-1-pentene	Ethanol	28	Ethyl 3,5,5-trimethylhexanoate	96.1	23
22	4-Methylcyclohexene	Ethanol	80	Ethyl 4-methylcyclohexane carboxylate[d]	80.0	42
23	cis-2-Heptene[c]	Ethanol	72	Ethyl 2-methylheptanoate Ethyl octanoate	57.2 24.2	41
24	1-Heptyne[c]	Ethanol	96	Ethyl 1-heptene-2-carboxylate Ethyl 2-octenoate	62.3 37.7	39
25	1-Octene	2-Chloroethanol	51	2-Chloroethyl nonanoate	80.7	21
26	1-Octene	2-Propanol	58	Isopropyl nonanoate	91.1	46
27	1-Octene	n-Hexanol	85	n-Hexyl nonanoate	85.8	57
28	1-Octene	Phenol	72	Phenyl nonanoate	83.2	14

[a] Run conditions: [alkene]:[ethanol]:[palladium] = 100:200:1; 100 atm; 85°C; 8 hr.
[b] Selectivity calculated basis total acid ester product.
[c] Initial [alkene or alkyne]:[palladium] = 50 : 1; 1-heptyne reaction time 4 hr.
[d] Minor product: ethyl 3-methylcyclohexane carboxylate.

Fig 2. The generation of acetic acid from synthesis gas illustrating the effect of the cobalt: ruthenium catalyst molar ratio

Product Profile:
acetic acid, ×
methanol, △
ethanol, ○
propanol, ▽
methyl acetate, ◇
ethyl acetate, □
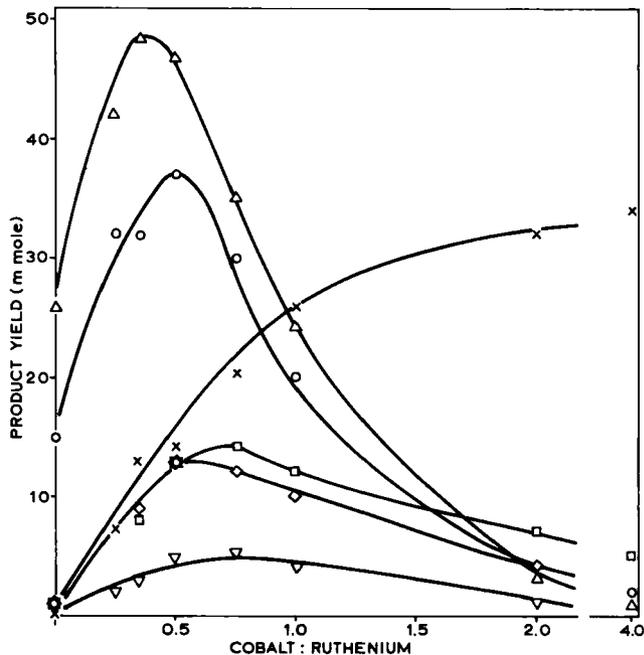
alkanol coreactant. However, this particular quaternary salt melts at 78°C, so, following carbonylation, the reactant mixture may be cooled to reprecipitate the inorganic catalyst components, thereby once again ensuring ease of separation of the crude product acid esters from the now resolidified palladium catalyst.

Intrinsic advantages of this case of carbonylation catalyst over its solvent-solubilised counterparts (17) would be in:

(1) The ease of product acid ester separation.

(2) Improved stability of the palladium catalyst during multicycling.

(3) Potentially higher concentrations of active palladium within the reaction mix.

The long-term life of these palladium-dispersed molten salt catalysts, particularly $PdCl_2[P(C_6H_5)_3]_2$-$[(C_2H_5)_4N][SnCl_3]$, has in fact been confirmed in multicycling experiments, with regeneration of spent palladium catalyst (particularly reoxidation of inactive Pd(O) species) by treatments with mineral acids, peroxides, chlorination and oxychlorination techniques. Chlorination in the presence of added chlorinated solvent (16), in particular,

does allow multicycling of the palladium melt catalyst, over 30 to 40 cycles, with little overall loss in specific activity.

The economic attractiveness of the Texaco SFA process (Equation ix) has been reviewed (18).

Conclusions

Clearly the myriad potential applications of the platinum group metals in melt catalysis has only just begun to be explored. The development of new classes of catalysts to produce aliphatic oxygenates from synthesis gas, beyond the generation of C_1-C_4 alkanols/diols/acids to more complex molecules, and their use with N-, P- and S-containing coreactants, are challenges for the future. The extension of this technology to oxidation, halogenation and refinery processes, particularly hydrocracking and isomerisation, has yet to be fully exploited.

The commercialisation of the novel syngas-to-aliphatic oxygenate processes outlined in this article will hinge primarily upon future economic projections, particularly the relative feedstock values of petroleum, versus coal- or natural gas-derived synthesis gas.

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Platinum Compounds in Cancer Chemotherapy

A seminar on "Organometallic Compounds in Cancer Chemotherapy" took place at the Physikzentrum, Bad Honnef, West Germany, on March 4th and 5th 1985. It was sponsored by the Heraeus Foundation set up for the furtherance of scientific research by Wilhelm Heinrich Heraeus, grandson of the founder of the German precious metal and speciality chemical company W. C. Heraeus G.m.b.H. Inevitably platinum complexes dominated the proceedings.

The clinical importance to date of cisplatin was summarised by Professor S. Seeber (University of Essen). After reiterating the significance of the drug in the treatment of genito-urinary tumours, he went on to indicate its potential use in combination with other drugs in the treatment of certain types of lung cancer, including small cell, adeno- and epidermoid carcinomas. Promising results are also being obtained on rarer oesophageal tumours.

Dr. M. J. Cleare (Johnson Matthey) summarised the current status of analogue studies. Second generation drugs have clearly emerged on the basis of comparable therapeutic activity to cisplatin associated with considerably reduced toxicity. Of these carboplatin (JM8) was the most advanced. Data from numerous clinical trials suggest that JM8 will be registered for use in ovarian cancer in the near future. There is evidence to suggest that some of the cisplatin analogues, particularly iproplatin (JM9), may have a slightly different spectrum of tumour activity compared to the parent drug. However, Dr. Cleare felt that improved activity should be the subject of research aimed at a third generation platinum drug. A likely approach was to design targeted platinum complexes with some biological selectivity towards tumour cells. In this regard, Professor J. Karl of Regensburg University described some elegant studies aimed at developing platinum complexes with specific activity towards hormone dependent breast cancers. Platinum complexes have been synthesised using ligands which have proven ability to bind covalently to estrogen receptor sites. This work could be of significance in extending platinum drug activity but caution must be expressed; a genuine advantage of complex over free ligand has yet to be established.

Active platinum complexes with bidentate organic diamine ligands were described by Dr. H. Brunner of Regensburg University and Dr. H. A. Meinema (TNO-Utrecht).

The reaction of platinum compounds with DNA seems to hold the key to their anti-cancer activity. Dr. N. P. Johnson of CNRS, Toulouse and Dr. B. Lippert of the Technical University at Munich, discussed studies on model Pt-DNA adducts. It appears clear that the primary site of DNA attack is the N7 position on guanine. Ninety per cent of the mono-functional platinum lesions rapidly chelate with another adjacent purine base (primarily but not exclusively guanine).   M.J.C.