[illegible]

Partial oxidation reaction characteristics of oil sludge ([illegible]

[illegible]

[illegible]

Abstract

In order to provide useful information for the resource utilization of oil sludge by oxidative thermal decomposition, the reaction kinetics and products analysis of pyrolysis in the presence of oxygen are studied. A three-reaction model is proposed for the oxidative thermal decomposition of oil sludge. The first reaction is pyrolysis reaction without oxygen, while the second and third reactions are oxidative reactions. This model can be used for the situation with concentration of oxygen below that of air. In the accumulate gaseous product, CO_2 has the highest concentration. The temperature ranges corresponding to the maximum production rates of CO_2 and of CO, HCs (hydrocarbons) and H_2 are 788 ~ 813 K and 713 ~ 738 K, respectively. The distillation characteristics of liquids from the oxidative thermal decomposition of oil sludge are closed to the commercial gasoline and diesel oil.

keywords: oil sludge, partial oxidation, pyrolysis, resource utilization, thermogravimetric analysis

[illegible]

â ¢ß_ê æ¢±â ¤ ©

NK ú ê ¼ ß d

ã ëi ã ê ä ä ¢ú ê ½ ¦ç 1997 ä ¼ â 12 â ħ ï ¯ ã ñ ß ö Ð ú þ ¶ ñ ë ú ¢ (S611) â ß ç æ ë - è ó ¢ ç ê ß ë Ï ê ½ ñ ð ¸â ¤ ® æ ã ð þ Ï ê õ î þ Ï ü í ü 24 â ® ß ¼ ú ô ý ¢ ã û ê ¼ ß `

3. ú ê ä þ σ ã ß d

æ è ä ä ¢ú ê ½ 5 ~ 10 mg ç ¢ ã ë û ä ß ¼ ï Ţ ă ħ ô ¯ ø é ß 30 mL/min ß ã õ ă ë æ Ă ã ą ë ø Ĝ ø é 378 K (105 à) 16 â ® (overnight) ß ^ û ç µ ħ ô ¯ ã ä ¼ ã ă Ą ß ô » ç ú ô ý ¢ ã ß ä ÷ ã ñ Ă ð ã ñ ð ã ú â ħ ß ¼ ú ô ð ´ ã þ ê 1RKO ß NOKU ç j ONKU=hL«§¬ ß æ ã ê å ą ã è ă Ų ñ ŭ Ţ ä ß æ Ģ â ă ą ð ¯ ã þ ê 0KUPI=UKSO=ç 0MKVR=´-ªK=B=E è ă ì Ħ ß `

QK= ú ô ý ¢ þ ñ ê ì ¢ Ą å æ ß d

ã ê æ±å ã Ŏ ħ ¯ ì ą ã ð æ ¢ â þ ñ ê ê ġ æ ß õ ă ë Ą æ ñ Ą ã Č°°¦£¬§³± â ħ ä ß ã ß ^ ý ë ë Ą æ ñ Ą ã Ã ð ê å ß « ä â þ ë ã ß ă č þ ñ ð ã ħ ä ß ® ç ß ß d

$$r = \frac{dX}{dt} = A\exp(-\frac{E}{RT})(1-X)^n \, x l_0 z^{«}$$

$$= k(1-X)^n \, x l_0 z^{«}$$

°= ß ú ô ý ¢ þ ñ ð ß NL«§¬ ß ^

u= ß Ă ê Ą ÷EJF ß NJ=j ß ^

j= ß â þ ë ë ¢ û ħ ¯ ã EJF ß (W-W_f)/(W_o-W_f) ß ^

W ß â þ ë é ñ ă ë ß ç Č õ ß û ć ñ ¢ û ħ ¯ (mg) ß ^

W_O ß â þ ë ê ï ħ ¯ ß mg ß ^

W_f ß â þ ë ð ë ¢ û ħ ¯ ß mg ß ^

^= ß þ ð ä â ß ø°£¯³£¬¡·=¤~¡²-°I NL«§¬ ß ^

b= ß ê ß Ą ß ž¡²§´~²§-¬=£¬£°¥·I ©gL«-ª£ ß ^

o= ß ð ą ñ ú =Ą UKPNQ=$\times 10^{-3}$ kJ/mol K) ß ^

q= ß ó è ñ ă ß ß ^

¬I=«= ß â þ ñ ă =Ą°£~¡²§-¬=-°¢£°±F ß ^

©= ß ð°°¦£¬§³±= ñ ð ï ú =Ą NL«§¬F ß ^

xl_0z=W= ì į ý ë =EJF ß `

RK= è ä ä ¢ú ô ý ð ă ä þ ß d

æ ä è ä ä ¢ú ê ¼ 300 mg ç ¢ ã ë û ä ß ¼ ï Ţ ă ħ ô ¯ ø é ß 30 mL/min ß ã õ ă ë æ Ă ã ą ë ø Ĝ ø é 378 K (105 à) ß ^ û ç µ ħ ¯ æ ã ® ê ę ă ă Ą ô ¯ ã ® ç 5% é ß ô » ç ú ô ý ¢ ã ß ì ą ð ă ă ê î â þ ý ü ą ð ă ă ñ þ ß ą ð ă é ê Ŀ ã ú ô ð ´ ê 1.2 K/min ß ì į ą ð ¯ ã þ ê 4.83 ß 8.62 ç 20.95 vol. % ß ã þ õ ă æ 425 K é ß ¼ ã ï Ă õ ä ê î Ţ ă ð ă é 873 K ß ¼ å ý ü ą ð ă ß ä ã æ 25 K ô ß ë â ħ ê ß ¼ ì į ą ð ¯ ê 20.95 vol. % ß ¼ ã ï Ă ú õ ä ê þ ¢ ß ã ß ¼ ê â 25 K ô ß ö ă ë ¢ñ İ â â Ą õ ă ã å ą ð ă é ê ß ã ¢ ô ð ¢ ð ă é ĉ é ½ ä ê ì ¯ 378 ~ 873 K ú ô ý ¢ þ õ ă ë ¢ñ İ â ß ç â ¤ 298 K ß ¼ å ü ¢ â Ï ú ¢ ü ä ê ê d ă ß ì ą ð ă â þ ô ã ê : THCs (hydrocarbons) ß ^ CO ß CO_2 ß H_2 ß ã þ ù û â þ ê î ¢ ę ë ù -Ĵ ä ĳ ý Ă ą ª ì ù ë -(GC-FID, GC ß Hewlett Packard Inc, HP 5890 Series à ß ß FID ß flame ionization detector) â Č ¢ ę ë ù -Ĵ û Č ù ë -(GC-TCD, GC ß China Chromatography 8900 ß TCD ß thermal conductivity detector) ß ð ¢ ð ă â þ ô ã ê ê -é ¼ ú þ þ ž ß ^ è -é ¼ BTEX (benzene, toluene, ethylbenzene, xylene) å ð ¯ ã þ ß ã þ ù û ê î ¢ ę ë ù -Ĵ ý s Ă ą ª ì ù ë -(GC-FID) ß `

ã ¶ß_ó ð ¢ ñ ì û ë

NK= â þ ñ ê l

ä ì ą ð ¯ ã þ ê 0MKVRI=UKSO ç 0KUP=´-ªK=B â ä å ê ë Ą ä ñ ã ®§¥³°£±=N ß 0=ç =P ç ß ß ` ÷ ñ ¢ í Ă ğ ô ý ¢ ä å ê ë Ą ä ñ ê ï $NVVVF ã § ó -ð ß â â φ ê ä ñ ą ð ¯ ã Ă ê Ą ÷Eu=Z=NJjF ÷ ¢MKR â å ß ú ê ë Ą ä ñ ð ã ¢ ñ í Ă ğ ô ý ¢ l â ë è ß ã ž ã § ð ž â ä ñ ą ð ¯ ã å ô ý Ă ê Ą ð ´÷ ¢MKR â å ã ä -é ñ ê Ă ó Ă ğ ô ý ß 1 į ą ú î ¢ ä þ ß ë ¢ u ÷ ¢MKR â å ß ¼ ã § æ ã Č Ă ğ Ĵ ó ý ¢ â þ ñ ê ä ħ ä ß ï $=NVVVF ß ä u ê MKR ä Ĕ â å ß ã ¢ ß Ą ê â þ ¢ ñ ß ã ĝ ã ê ê á ä è â þ ñ ß æ Ģ û ¢ñ ą þ ê MKRN¼MKTO ç j MKTP¼N ß ä æ ê þ ñ Č į ą ñ ¢ ä þ ß ê ¢ â ã m ì ą ð ¯ ä å ô ý ß ¼ æ ą ę ã ä -â þ ñ ð =E°NI °0I=°pF â ħ ä ß § þ ê ã Ă ® ß d

°£~¡²§-¬=NI ã =ú=Z=M= ý -æ Ï=Z=N ß ^

$$r_1 = 7.69 \times 10^5 \exp(-\frac{69.93}{RT})(1-X)^{2.94}$$ ß ^

°£~¡²§-¬=OI ã =ú=Z=M= ý -æ Ï=Z=N ß ^

$$r_2 = 1.66 \times 10^{17} \exp(-\frac{208.67}{RT})(1-X)^{2.91}[O_2]^2$$ ß ^

°£~¡²§-¬=PI ã =ú=Z=M= ý -æ Ï=Z=N ß ^

$$r_3 = 9.45 \times 10^7 \exp(-\frac{120.87}{RT})(1-X)^{1.36}[O_2]^{0.32}$$ ß `

2. ú ß ß Ó ñ ã ê á â ¢ Ĺ

[illegible] (M) [illegible] Figures 1, 2 and 3 [illegible] 5.2, 12.8 and 21.8 K/min [illegible] 20.95 vol. % [illegible] (R^2) [illegible] 0.9909, 0.9933 and 0.9970; [illegible] 8.62 vol. % [illegible] R^2 [illegible] 0.9905, 0.9961 and 0.9915; [illegible] 4.83 vol. % [illegible] R^2 [illegible] 0.9823, 0.9931 and 0.9804 [illegible] X [illegible] 0.5 [illegible] X [illegible] 0.5 [illegible]

$$\text{oil sludge} + O_2 \begin{cases} \xrightarrow{k_1} \text{volatiles } V_1 + \text{residues } M_1, \\ \xrightarrow{k_2} \text{volatiles } V_2 + \text{residues } M_2, \\ \xrightarrow{k_3} \text{volatiles } V_3 + \text{residues } M_3. \end{cases}$$

3. [illegible]

[illegible] Eincineration efficiency [illegible]

[illegible]

4. [illegible]

[illegible] HCs [illegible] (C_1; [illegible] 0.52 wt. %) [illegible] HCs [illegible] 713 ~ 738 K [illegible] 633 ~ 688 K [illegible] Figure 5 [illegible] H_2 [illegible] 663 ~ 763 K [illegible] 713 ~ 738 K [illegible] CO_2 [illegible] 788 ~ 813 K [illegible] 788 K [illegible] 813 K [illegible] CO [illegible] 713 K ~ 738 K [illegible] CO_2 [illegible] HCs [illegible] H_2 [illegible] CO [illegible] 713 ~ 738 K [illegible] 733 K [illegible] 0.7779 [illegible] 663 K [illegible] 0.7944 [illegible] 438 K [illegible] 0.9889 [illegible] Figure 4 [illegible] 613 K [illegible] 613 K [illegible] 613 K [illegible] 613 K [illegible]

5. [illegible] BTEX [illegible]

[illegible] BTEX (benzene, toluene, ethylbenzene, iso-xylene) [illegible] benzene [illegible] toluene [illegible] benzene [illegible] toluene [illegible] benzene [illegible] toluene [illegible] Figure 6 [illegible] Benzene [illegible] 738 ~ 763 K [illegible] Toluene [illegible] 788 ~ 813 K [illegible] Ethylbenzene [illegible] iso-xylene [illegible] benzene [illegible]

6. [illegible]

[illegible] 298 K [illegible] ASTM-D2887 [illegible] GC [illegible] C6 ~ C44 [illegible] GC [illegible]

[illegible] 20.95 vol. % O_2 [illegible]

ú ð ÿ ď Ě73 K ç Ð-ÿ }ð ď ħ -â þ â tâ æ Ġ ß â t ú |è â ß Ā â ð ď ħ -(20.95 TL - 873 – U) ß ´â ú ¦ ê ð }ò þ Ġ ğ }è ð ď ħ -(20.95 TL - 873 – L) ß ä z ç ă ģ â ä ß ê â tâ ú |ð ď ħ þ »í ú þ þ ză ß è - ä ā ¢ä 20.95 vol. % O_2 ý |è ā ú ð ÿ ď Ě63 K ç Ð ï -ÿ }ð ď ħ -é |ò ç ă ģ þ |ð ¯ò ß ê ü ğ }ð þ ê ø ð ď ħ -(20.95 TL – 763) ß ä ď -ä ā ¢ä 8.62 vol. % O_2 ý |è ā ú ð ÿ ď Ě73 K ç Ð-â ş }ð ď ħ -é |è î ô Ā â ý è ð ď ħ -(8.62 TL – 873) ß ï ká ð ď ħ - ú þ þ ză è ó ð ß æ ê Ā ê â ā ß â ď ä Ě ā §ā þ ā ę ü õ Ð±è -(light naphtha) ß è õ Ð±è -(heavy naphtha) ß ù ò ę -(light gas oil) ß ç }è ě ę -(heavy gas oil) ß `ç }æ ę î ð ¼â ě -ú þ þ ză è ó ð ď į ö ß ´ä ®Table 2 ç ā Ě ã ďTable 2 â ā §ê ā ß ´è - ä ā ¢ä 20.95 vol. % O_2 ý |è ā ú ð ÿ ď Ě73 K â å â ú |è -(20.95 TL - 873 – L) ç ú ð ÿ ď Ě63 K â ð ď ħ -(20.95 TL – 763) ä ē ę é ó þ þ ză ó ð è ß ´ã ù ¤98 ó ï÷ æ ¢è -(GL – 98) è ó þ þ ză ð ē ä é ï }ê ę ß ã ã ¼â û ü ě ă ¢è -(GL) ß 92 ó ï÷ z æ ¢è -(GL – 92) â Ð5 ó ï÷ æ ¢è -(GL – 95) â å þ þ ù ză ð ā â é Ě ö ß ä ď -ä ā ¢ä 8.62 vol. % O_2 ý |è ā ú ð ÿ ď Ě73 K â ş }ð ď ħ -(8.62 TL – 873) ß æ Ġ þ þ ză è ð ā é |ù ü ě ă ģ -(DL) è ø ú þ |þ ză ð ā é ê ê ę ß `ä ę Ġ ë ē Ð±è - (heavy naphtha) è å ô ¯â î ě ă ģ -(DL) ÿ ê è ê ķ.69 wt. % ß ´ù ò ę (light gas oil) è å ô ¯õ ā æ é |ê ķ `6.33 wt. % ß `ä ğ ě ę ¼û ħ î ě ă ģ - (DL) ÿ ā -ß 20.95 vol. % O_2 ý |è ā ß ê -ä ā ¢ú ð ij ö ď Ě73 K ç Ð-ÿ }ð ď ħ -â â ú |ò Ā ð ď ħ - (20.95 TL - 873 – U) æ Ġ þ þ ză ð ā ş û ü ě ă ģ è -(DL) ê ę ß ´ä ę Ġ ě ę -(heavy gas oil) ð ā æ ê ķ î ě ă ģ -(DL) î ê ķ6.22 wt. % ß ´â ď ò ę - (light gas oil) ð ā â î ě ă ģ -(DL) ê ķ `21.57 wt. % ß `ä ză ğ ě ę ¼û ħ ĺ ě ă ģ -(DL) ì ß `

ã ď ê tó ð ď §ê ß ´ï į ô ¯õ ß ê -ä ā ¢ú Ĵ ó ÿ ç Ð-ð ď ħ -é ¼û ħ ä -ß `ä 20.95 vol. % O_2 ì ß ê -ä ā ¢ú ð ÿ õ ā æ Ī63 K â ą Ě73 K ç Ð- ð ď ħ ß ´ä ză ā þ â tâ æ Ġ ß ê é ¼û ħ -ß ä ę l ú ð ÿ ď Ī63 K â ð ď ħ -ù ú ð ÿ ď Ě73 K â å r ú |ð ď ħ ß æ ê ê ¼û ħ ß ę ß ä ză ê ä |ò ªä ú ð ij ö õ ā ā ĉ è ď ð ď ħ -é ¼û ħ Ě ß ´ë ĉ -Ă ¼Ă Ī ò î ß ä ą æ ê Ġ þ þ ză ð ā â ü ď ě ¢è -ð ā ê ę ä ß ā § ą ä è ¢ú ð ÿ ç Ð-ð ď ħ -ä ü ď ¼þ ā ê t è ò ķ ß `

7. ð ď ħ ă ā BTEX å ô ¯â þ o

BTEX ê â ü Ā |è -é ½é ¼û ħ ø ë -é ú ð â]; ñ ¯ ï }BTEX å ô ¯ä |â â -é ß ´è ā ě Ç ā ê Ę ü Ę æ â |â ý é |ß `ã ªä |ú ð ÿ ď -é ¼û ü ð ¼â ě -é ¼â å BTEX è ô ħ ¯â þ ´ä ®Table 3 ç ā Ě ã ďTable 3 â ā §ā ğ Ě98 ó ï÷ æ ¢è -(GL – 98) ß 95 ó ï÷ æ q è -(GL – 95) ß 92 ó ï÷ æ ¢è -(GL – 92) ù ü ě ă ¢è - (GL) æ ĢBTEX å ô ¯â ß ä ï }ï ß ã ã ď ĢBTEX ð ē ä ā §ó -ð ß 98 ó ï÷ æ ¢è -ù ¤95 ó ï÷ æ ¢è -ê ę ß ´ä ď 92 ó æ ¢è -é |ù ü ě ă ¢è -ê ę ß ä 20.95 vol. % O_2 â ß è -ä ā ¢ú ð ÿ ď Ī63 K â ð ď ħ -(20.95 TL – 763) ù ú ð ÿ ď Ě73 K â å ú |ð ď ħ -(20.95 TL - 873 – L) ß ´æ ê ĖTEX ÿ }å ô ¯ê ę (ş6302.3 vs. 82988.2 mg/kg) ß ä ę -ä ā ¢ú ð ÿ ď Ī63 K â ð d ă ħ æ Ģoluene å ô ¯ê ú ð ÿ ď Ě73 K â å ú |ð d ă ħ -è Ð.3 ë ß ´iso-xylene ê ļ4.62 ë ß ´ä ļenzene é |ê ü.74 ë ß ´ethylbenzene ê ü.75 ë ß ä æ ê ĉ á â ¢benzene ð ā â ş8 ó ï÷ æ ¢è -ù ¤95 ó ï÷ æ ¢è -î è â â ß æ Ġ ªBTEX ð ā â ß ą ā ºĒ ď ě ¢è -å ß ` ä ā §í ě ä ză ú ð ÿ ď ká ñ ß þ Ħ â ü ģ Ą è ā ò Ā |â â ß ´ä ză -BTEX ÿ }å ô ¯ō ĺ ď ě ¢è -å ß è - ä ā ¢ä 8.62 vol. % O_2 ý |è ā ú ð ÿ ď Ě73 K â å ÿ }ð ď ħ -(8.62 TL – 873) ù ¤20.95 vol. % O_2 ý |è ě â ß ú ð ÿ ď Ě73 K ç Ð-â tú |ò Ā ð ď ħ -(20.95 TL - 873 – U) æ ê ĖTEX ð ā â ß ü ě ă ģ -(DL) ö ê ę ;í ä ę -ù å `ç ā ºĒ ď ¼â ě ¢è -â ð æ ê ļ ú ð ÿ ç Ð-ð ď ħ -ß ã ºĒ ú ð ÿ ç Ð-ð ď ħ -â å ethylbenzene ù ¤iso-xylene è å ô ¯â ß â ß ´ã ğ Ě ä ÿ }ì ą ð ê â â â æ Īethylbenzene ù ¤iso- xylene ß ^ã ä þ |ô ß ą ð é á â æ Ī è ø ethylbenzene ù ¤iso-xylene ý |è ā å ß ´å ß ē §e ð ¸ö ď ß ä ā §í ě ä ză ā þ Ħ â Ą è â î õ ß â ñ ì þ Ħ ā ç ú á þ ď |ÿ ą ā ß `

8. ð ă ě ô ħ ¯â ş ă

ã ü ā â ä ü þ Ħ ā ú ð ÿ ď -ä ā ß æ ę ă é ä ê ā §þ â ü ò ę298 K) â å ą ß ì ą ħ ò â â ð ď ħ ú ð ÿ ď â ď ª ē ħ ä 20.95 vol. % O_2 ý |è ā ß ã ú ū é ā ą è EKOßNOKU ç ÐNKU=L«§¬ ì ß ´è -ä ā ¢ú ð ÿ õ ā æ Ī1123 K ì ě õ ď ªê å ß å ß ªé ğ ĉ ā ē â ą ā ß æ ą ô ¯ä é ü ð ÿ ď é ¼ è ô ħ ¯â ê þ ą ą è 2 ß 2.14 ù ¤1.41 wt. % ß ä ď ä 8.62 vol. % O_2 ì é |ê ĉ.98 ß 1.75 ù ¤2.64 wt. % ß ` ä 4.83 vol. % $O_2$ ì é |ê ĉ.97 ß 4.23 ù ¤6.28 wt. % ß ` ã ď ê tó ð ď §ă ğ Ě ā ú û ô ¯õ í ß â þ õ ä á â ā ß ä ză ñ ď ô ¯õ í ß ä ą ā ü ą ô ÷ ü ê ğ ď ü ª å ô ¯ê ó ā ¢è |â ą ă ğ ä 20.95 vol. % O_2 þ Ħ Ð ß è -ä ā ¢ú ð ÿ õ ā æ Ě73 K è õ ď ªê å ² ô ¯â ý }ú ð ÿ ď -ä ā ¢ô ¯ê ø4.13 wt. % ß ´â ď ď ħ ê ô ü ¯ç ħ â ę ê 31.96 wt. % ß ´â þ ą ß ą ý |è ě ÿ }ç }è ð ó ĉ ą ħ {ä ę ħ â ą ´(ã æ ^H_2, CO, CO_2 â ĦCs, ä ą ā å CO ù ¤CO_2 â â å ą ô ¯)ß ^ æ Ģ ħ â ą ê 57.18 wt. % ß ò â ñ ď ªê å ô ¯ß _

ðdă ħ ê ô ù mì ặ ħ ê ô ß æ Ģ }ä {ä ê ä ñ 3.27 wt. % ß ` ó è ©÷ æ 100 wt. % ã §í ê lä ž ð å ặ â ñ H_2O ç ºã ô ò â ǎ §í ǎ ð dă å kü ç ú ô ğ ð dă ħ ä ê ð ¼â å ½è ø Ĝ ³â ę Đ m ß ë vä 20.95 vol. % O_2 þ Ⱨ Đ ß ê ä à ¢ú ô ğ ð ǎ ã æ 763 K ì ß æ ộ ď ü ªè é ¦ê ô Ā ô ķ ç qă ß hã _æ ộ ď ªè å ²ô ä ý }ú Ĵ ó ğ ě ä à ¢ô è ø 8.77 wt. % ß ä ð dă ħ ê ô ç Đ Ĺ â ộ é ¦ê 36.68 wt. % ß ` ä ž ñ ð ě ô ğ ð ǎ ě å `
(763 K ß ê 873 K) ß å ž ä ñ ď ªè å ²ô ö Ĺ ę 8.77 wt. % ß 4.13 wt. %) ê lä ш ð ¸è ß ä ộ dă ħ ê ô ä ú ô ğ ð ǎ ę 763 K ì ã ô Ĺ ß ê ã §í ǎ ž ä ± ú ô ĳ ö ç Đ â å ặ ŏ ǎ ã ºå kü ç ä ê ð ¼â å ½è ø Ĝ ³ â ę Đ m ß ä 8.62 vol. % O_2 ý]é ǎ ß è ä à ¢ú ô ĳ ö ð ǎ æ 873 K ì ß ñ ď ªè å ð ¹ê ğ Ġ ã ê ê ę q ă ß æ ộ ²ô ä ý }ú ô ğ ě ä à ¢ô è ø 3.27 wt. % ß ^ ä ð dă ħ ê ô ç Đ á å ộ é ¦ê 27.83 wt. % ß æ Ģ ð dă ħ ê ô å ²ô â 20.95 vol. % O_2 þ Ⱨ Đ ý å ß ^ ã §í ě ę ž ê ð ã ö á ä þ ªè ø ặ ß hä æ ā ê ð ¼â å é ð kå kü ç ä ê ô Ĝ ³ø Ĝ þ ß ã ď Ħ ã ý ǎ ó ð d ã §ã ǎ ğ ß Ǩä ä ñ þ Ⱨ Đ ç Đ ê ê ð dă ß æ ộ ǎ ´ â į Ā ğ ô ğ ǎ ŕâ å ǎ ´(69.63 wt. % (ï §1999)) ÿ å ß ` ã §í ě lä ž ä ã ¨ñ ß þ ä ũ ĝ Đ mì ặ þ ã æ CO ù m$CO_2$ ç Đ ě m ß ê ė vâ æ ã Č į ß ð lã x ð lã x è ę í Ā ğ ô ğ ǎ â ã ď ǒ å ú ô ğ ǎ þ å å ÷ ã ß ã _ã §ã ò á ě é ½é ¼û ß ú tã x ð dă ħ ð å ´è ø ö Ě ã ê lã ²ã ¼â ]ë ǎ §ã ê ğ ±è ô Ħ ß `

â ß _î ǎ Đ Ǧ «

NK= ï §ú õ ß ªè ä à ¢ö ð â Ą ğ ±ß ä ê cî ºî ĩ ~ ê ū ç £ë ő ºï]ā æ ğ ±ë ®ó £ä æ ñ ķ § ß ë ®ó £û ± ö ß kp`USJ`m`JbJMMOJMMO ß NVVV ß `
OK= â ặ ü ß ªú ï è ő _ð ¸” ß â ğ Ê č ď
=== ä õ â ã ß ã ¶Ą tã ¶ã |ß NVVR ß `
PK= ò ý ú µß ª= ò ǔ ä æ yì æ Đ = ú è è ¢ä å n ã ’Č ß ð Ǎ ç ß ³õ ½ò ǔ å Ĝ kù mó ǎ â ĝ mõ ºû ě â ĝ ß ®®K=PUJN=¼U ß ã ¶Ą tã ¶ã |ß NVVP ß `

â ß _÷ ě ũ ş K

Table 1. Total gaseous product concentration (á ¥ g/L) for oxidative thermal decomposition of oil sludge. Heating rate (HR) = 5.2 K/min.

Table 2. Distillation characteristics of liquid products from oxidative thermal decomposition of oil sludge in this study and of some commercial oils. TL, GL, DL, FL, HL : total liquid from oxidative thermal decomposition of oil sludge, gasoline, diesel oil, fuel oil and heavy oil. 20.95, 8.62: denote vol. concentrations of O_2 in carrier gas. 873, 763: denote temperatures of thermal treatment. U, L = upper, lower layers. 98, 95, 92 = trade names of unlead gasolines.

Table 3. BTEX concentrations in liquid products from oxidative thermal decomposition of oil sludge and of some commercial oils. HR = 5.2 K/min. Other notations are the same as in Table 2.

Figure 1. Comparison of residual mass ratio (M) predicted by proposed three-reaction model with experimental data at different heating rates (HR) for oxidative thermal decomposition of oil sludge in 20.95 vol. % O_2. 1(Δ), 2(0), 3(×) ß HR = 5.2, 12.8, 21.8 K/min. Line ß computed ß symbol ß experimental ß R_1^2, R_2^2, R_3^2 = 0.9909, 0.9933, 0.9970. T = temperature.

Figure 2. Comparison of M predicted by proposed three-reaction model with experimental data at different HR for oxidative thermal decomposition of oil sludge in 8.62 vol. % O_2. The notations are the same as in Figure 1. R_1^2, R_2^2, R_3^2 = 0.9905, 0.9961, 0.9915.

Figure 3. Comparison of M predicted by proposed three-reaction model with experimental data at different HR for oxidative thermal decomposition of oil sludge in 4.83 vol. % O_2. The notations are the same as in Figure 1. R_1^2, R_2^2, R_3^2 = 0.9823, 0.9931, 0.9804.

Figure 4. Instantaneous gaseous product and residue oxygen concentrations for oxidative thermal decomposition of oil sludge in 20.95 vol. % O_2. HR = 5.2 K/min. 1, 2, 3, 4, 5 : CO_2, CO, HCs, H_2, O_2.

Figure 5. Instantaneous gaseous product concentrations for oxidative thermal decomposition of oil sludge in 20.95 vol. % O_2. HR = 5.2 K/min. 1, 2, 3, 4, 5, 6, 7 : C_1~C_2, C_3, C_4, C_5, C_6, C_7 and C_8.

Figure 6. Instantaneous gaseous product concentrations of BTEX for oxidative thermal decomposition of oil sludge in 20.95 vol. % O_2. HR = 5.2 K/min. 1, 2, 3, 4 : benzene (B), toluene (T), ethylbenzene (E), iso-xylene (X).

Table 1.

	H_2	CO	CO_2	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	HCs[a]	O_2	N_2
4.83	OMOKUV	QTSVKPQ	QVPNUKQR	NUOSKPP	TPOKRT	QMVKPS	TRPKON	USUKSQ	UTSKTU	QSNKRP	OTRKOT	NTNKNP	SPTQKUO	OTQNRKRS	VRUVNUKT

vol. % O_2	EORKNPF[i]	ENQRKNPF	EUSPKPSF	ENNVKOSF	EQVKQUF	ERUKOTF	EVTKPNF	ENMSKQVF	ERSKNRF	EUKMUF	ENQTKONF	EROKQQF		EQMMKQNF	EQOVQKTF
Wt. %[d]	MKPP	TKUS	UNKPM	PKMN	NKON	MKST	NKOQ	NKQP	NKQR	MKTS	MKQR	MKOU	NMKRN		
8.62 vol. % O_2	:	TRMRKSS EPKSMF	UTNMQKVU ETQKONF	NUUOKTV EPVKMMF	SUTKPM ENTKOOF	RNNKTM ERSKORF	RMSKNU ENTNKNUF	UPMKTQ ETNKUSF	UPUKQQ EOKPVF	PUVKPP ENMKMUF	NPQKSR ENRKVQF	PPKUP ENPKMOF	RUNQKVS	RRMUUKSQ ENQNKVOF	VOTTQSKV ENPQKTF
Wt. %	0	TKQT	USKTP	NKUT	MKSU	MKRN	MKRM	MKUP	MKUP	MKPV	MKNP	MKMP	RKTV		
20.95 vol. % O_2	= = QNKOP	= NQUNTKUR EPVSKQRF	NRVPSTKMS EUVNTKRNF	OPTQKUP ENPKSVF	MKMM	TTVKTO ETKMPF	UTVKPM ENUKVQF	UPNKOS EORKUPF	TQUKQT EOVKPNF	POQKQM EVKQTF	NNSKVR ERKTUF	RPKMV EOOKOTF	SNMUKP	NVUNVOKS EPNNQKPF	VOOUUMKR EUOROKQF
Wt. %	MKMO	UKOO	UUKPT	NKPO	MKMM	MKQP	MKQV	MKQS	MKQO	MKNU	MKMS	MKMP	PKPV		

a: HCs = sum of C_1, C_2, C_3, C_4, C_5, C_6, C_7 ,C_8 , C_9. b: unit in á¥g/L.

c : numbers in parentheses are standard deviations (á¡). d: based on sum of H_2, CO, CO_2 and HCs.

Table 2.

	20.95 TL–873-U	20.95 TL-873-L	20.95 TL-763	8.62 TL-873	GL-98	GL-95	GL-92	GL	DL	FL	HL
Light naphtha 343 ~ 366 K	0.19[a] (0.04)[b]	9.98 (0.81)	9.67 (0.50)	0.16 (0.06)	8.49 (2.67)	5.36 (0.32)	6.7 (1.90)	10.07 (1.91)	0.04 (0)	0	0
Heavy naphtha 366 ~ 477 K	13.11 (1.75)	65.52 (2.96)	63.77 (1.09)	14.53 (1.47)	64.37 (2.21)	70.95 (4.28)	67.9 (5.16)	62.93 (0.24)	7.84 (2.34)	4.03	0.29
Light gas oil 477 ~ 616 K	65.70 (1.1)	23.49 (3.66)	24.58 (1.03)	80.94 (1.34)	26.59 (3.4)	23.31 (4.40)	24.88 (5.22)	26.15 (2.65)	87.27 (1.42)	46.01	23.88
Heavy gas oil 616 ~ 811 K	21.00 (4.00)	1.01 (0.22)	1.98 (0.23)	4.37 (0.19)	0.54 (0.51)	0.38 (0.19)	0.52 (0.39)	00.85 (0.25)	4.78 (0.99)	49.59	75.19
Vacuum residue ß8Ë1 K	0	0	0	0	0	0	0	0	0	0.38	0.64

a : unit in wt. % (excluding H_2O).

b : numbers in parentheses are standard deviations (á¡).

Table 3.

	20.95 TL– 873-U	20.95 TL-873-L	20.95 TL-763	8.62 TL-873	GL-98	GL-95	GL-92	GL	DL
Benzene (mg/kg)	752.45 (264.76)[a]	67863.86 (2513.55)	50277.83 (3054.74)	215.23 (21.58)	19477.11 (1424.07)	20539.5 (1866.42)	80695.64 (5112.16)	87934.59 (2089.98)	348.64 (12.05)
Toluene (mg/kg)	3271.57 (497.41)	10242.45 (2100.85)	23576.38 (1443.27)	2174.42 (1024.3)	68623.31 (6546.22)	70556.06 (18200.94)	56262.62 (2180.78)	64980.5 (6612.01)	1740.11 (210.86)
Ethylbenzene (mg/kg)	3467.6 (241.46)	2611.07 (471.62)	1958.42 (46.18)	1485.09 (514.8)	26681.42 (3256.5)	28518.36 (3893.52)	66046.73 (3364.8)	56523.15 (24912.93)	801.70 (296.6)
Iso-xylene (mg/kg)	673.99 (28.21)	2270.74 (488.48)	10489.72 (713.3)	1013.22 (288.98)	50318.16 (3229.71)	48812.97 (13016.27)	32586.1 (376.17)	34913.2 (336.57)	1829.1 (706.53)

a : unit in mg/kg (excluding H_2O).

b : numbers in parentheses are standard deviations (á¡).

Figure 1.

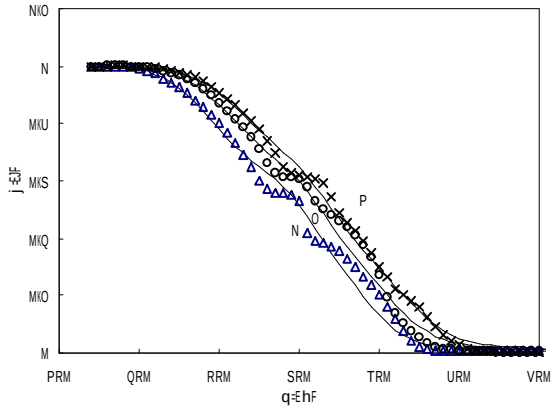


Figure 2.

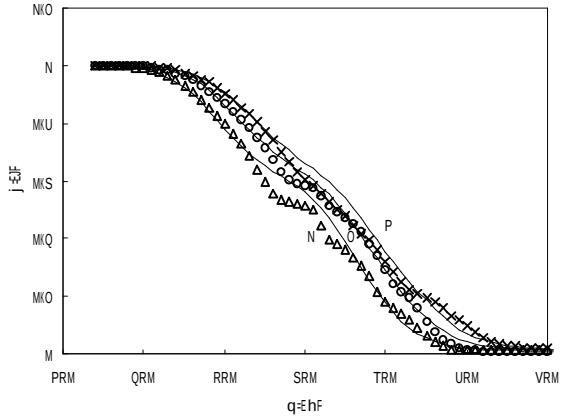
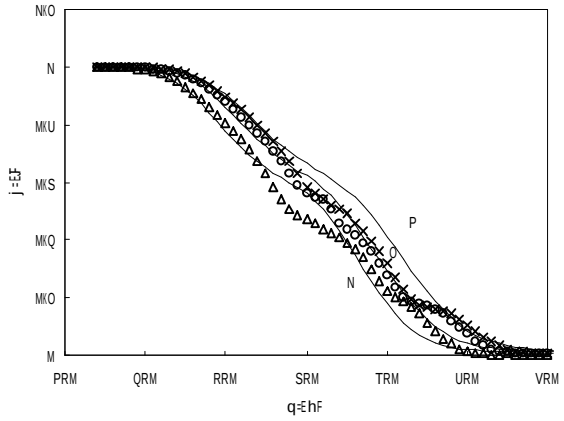


Figure 3.



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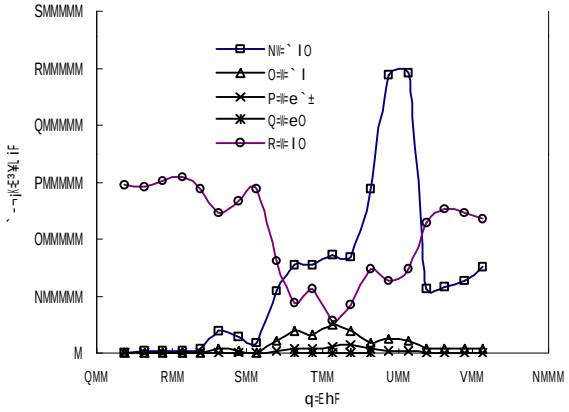

Figure 5.

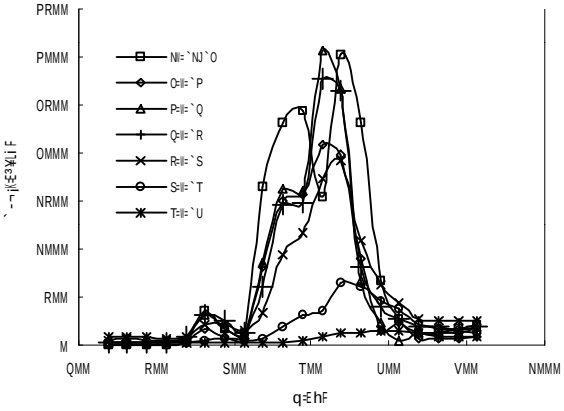

Figure 6.