An equation for the formation of methanol is given below:
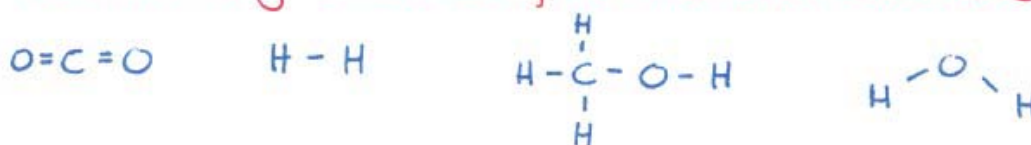
$$CO_{2(g)} + 3H_{2(g)} \rightleftharpoons CH_3OH_{(g)} + H_2O_{(g)} \quad [\Delta H = 49 \text{ kJmol}^{-1}]$$

Some mean bond enthalpies are shown below:

Bond	Mean bond enthalpy (kJmol^{-1})
C=O	743
C-H	412
C-O	360
O-H	463

a) Use this data to calculate a value for the H-H bond enthalpy.

① Draw rough sketches of the molecule structures:

O=C=O   H – H   H–C–O–H (with H above and H below on the C)   H–O–H (bent)

② Set up a Hess's law diagram:

$$CO_2 + 3H_2 \xrightarrow{-49} CH_3OH + H_2O$$

ΔH_1 ↘ ΔH_2 ↙

C + 6H + 2O

arrows point in when using bond enthalpy data.
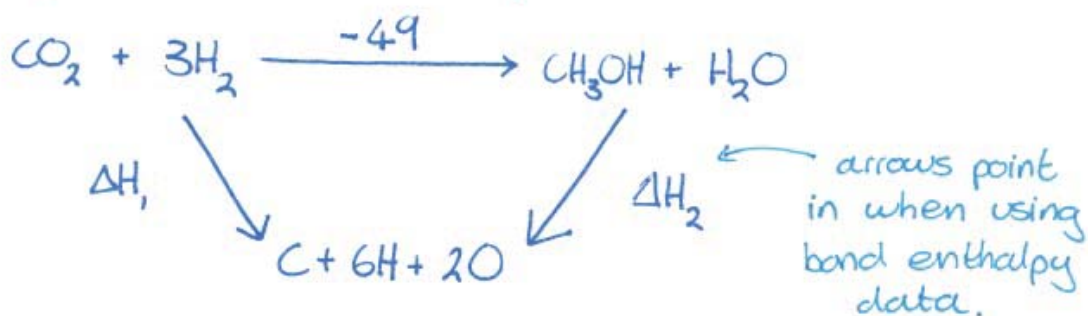
③ Calculate ΔH_1 and ΔH_2:

$\underline{\Delta H_1}$

2 × C=O = 2 × 743 = 1486
3 × H–H = 3 × x = $3x$
                              +
$\Delta H_1 \Rightarrow 1486 + 3x$

$\underline{\Delta H_2}$

3 × C–H = 3 × 412 = 1236
1 × C–O = 1 × 360 = 360
3 × O–H = 3 × 463 = 1389
                              +
$\Delta H_2 \Rightarrow 2985$

④ Use Hess's Law to find x:

$\Rightarrow \quad -49 = \Delta H_1 - \Delta H_2$ ← Remember to treat the arrows in the diagram as vectors.

$-49 = (1486 + 3x) - 2985$

$-49 = -1499 + 3x$

$\Rightarrow \quad 3x = 1450$

$x = 483.33\ldots$

$\Rightarrow \quad \underline{x = 483 \text{ kJmol}^{-1}} \quad (3\text{s.f.})$