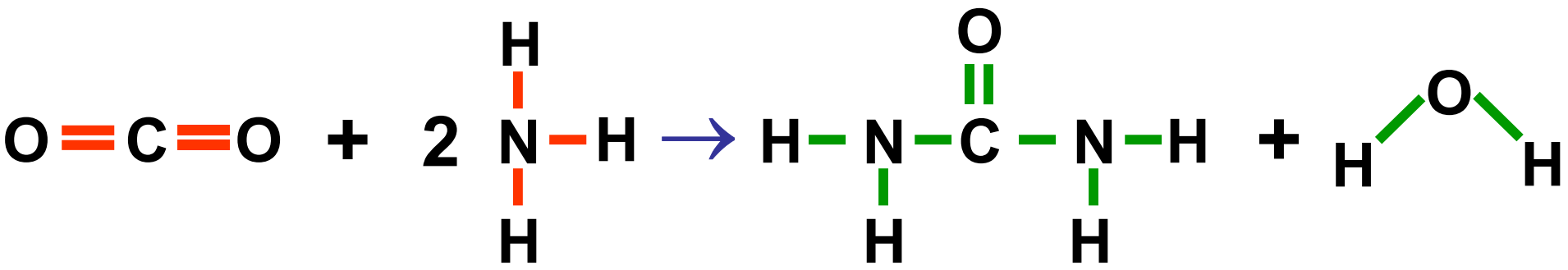
# Example Problem 9.49

**Use bond energies to determine the ΔH for the following reaction:**

$$CO_{2(g)} + 2\,NH_{3(g)} \rightarrow N_2H_4CO_{(g)} + H_2O_{(g)}$$




# Tabulated Bond Energies

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| H—H | 432 | N—H | 391 | Si—H | 323 | S—H | 347 |
| H—F | 565 | N—N | 160 | Si—Si | 226 | S—S | 266 |
| H—Cl | 427 | N—P | 209 | Si—O | 368 | S—F | 327 |
| H—Br | 363 | N—O | 201 | Si—S | 226 | S—Cl | 271 |
| H—I | 295 | N—F | 272 | Si—F | 565 | S—Br | 218 |
| | | N—Cl | 200 | Si—Cl | 381 | S—I | ~170 |
| C—H | 413 | N—Br | 243 | Si—Br | 310 | | |
| C—C | 347 | N—I | 159 | Si—I | 234 | F—F | 159 |
| C—Si | 301 | | | | | F—Cl | 193 |
| C—N | 305 | O—H | 467 | P—H | 320 | F—Br | 212 |
| C—O | 358 | O—P | 351 | P—Si | 213 | F—I | 263 |
| C—P | 264 | O—O | 204 | P—P | 200 | Cl—Cl | 243 |
| C—S | 259 | O—S | 265 | P—F | 490 | Cl—Br | 215 |
| C—F | 453 | O—F | 190 | P—Cl | 331 | Cl—I | 208 |
| C—Cl | 339 | O—Cl | 203 | P—Br | 272 | Br—Br | 193 |
| C—Br | 276 | O—Br | 234 | P—I | 184 | Br—I | 175 |
| C—I | 216 | O—I | 234 | | | I—I | 151 |

**Bonds**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C=C | 614 | N=N | 418 | C≡C | 839 | N≡N | 945 |
| C=N | 615 | N=O | 607 | C≡N | 891 | | |
| C=O | 745 (799 in $CO_2$) | $O_2$ | 498 | C≡O | 1070 | | |

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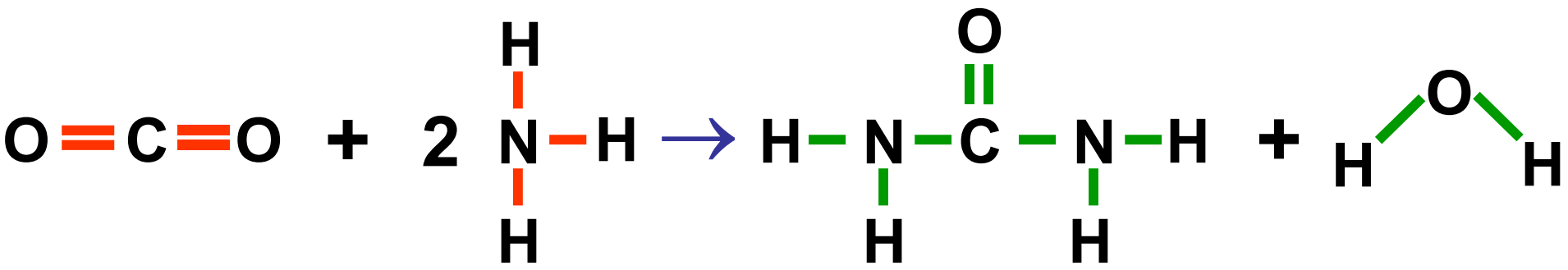

## Bonds Broken

- 2 C=O Bonds @ 799 kJ/mol
- 6 N-H Bonds @ 391 kJ/mol

## Bonds Made

- 4 N-H Bonds @ 391 kJ/mol
- 2 C-N Bonds @ 305 kJ/mol
- 1 C=O Bond @ 745 kJ/mol
- 2 O-H Bonds @ 467 kJ/mol

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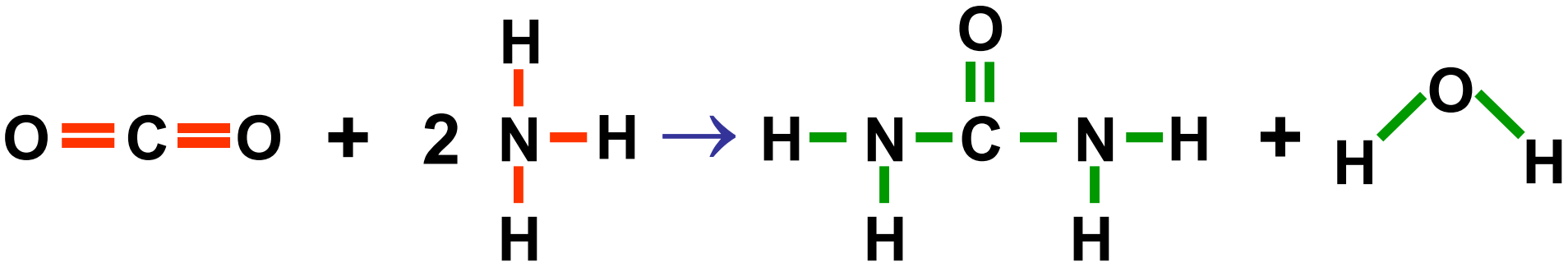

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**Total Energy (endothermic)**

$(2 \times 799) + (6 \times 391) =$

**3944 kJ/mol**

**Total Energy (exothermic)**

$(4 \times 391) + (2 \times 305) + (1 \times 745) + (2 \times 467) =$

**3853 kJ/mol**

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$$\Delta H = \Sigma B.E._{reactants} - \Sigma B.E_{products}$$

$$\Delta H = 3944 \text{ kJ/mol} - 3853 \text{ kJ/mol}$$

$$\Delta H = +91 \text{ kJ/mol}$$ *(rxn is endothermic)*